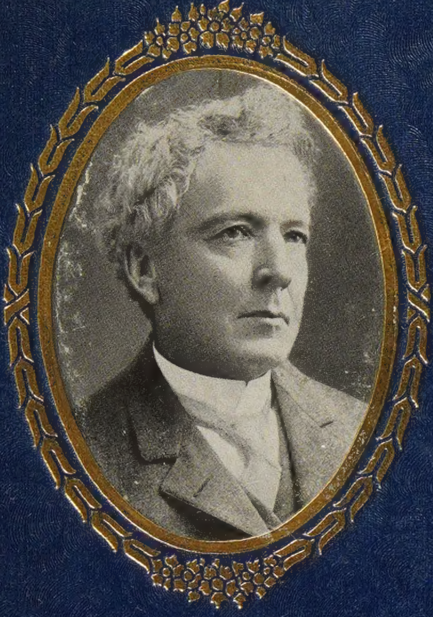

Luther Burbank

A Basket of Chestnuts

These are Burbank chestnuts of mixed heritage, combining the traits of European, American, and Japanese species. Their mammoth size seems all the more remarkable when it is known that they are grown on pigmy bushes, quite unlike the chestnut trees with which most of us are familiar.

LUTHER BURBANK

HIS METHODS AND DISCOVERIES AND THEIR PRACTICAL APPLICATION

PREPARED FROM
HIS ORIGINAL FIELD NOTES
COVERING MORE THAN 100,000 EXPERIMENTS
MADE DURING FORTY YEARS DEVOTED
TO PLANT IMPROVEMENT

WITH THE ASSISTANCE OF

The Luther Burbank Society

AND ITS
ENTIRE MEMBERSHIP

UNDER THE EDITORIAL DIRECTION OF

John Whitson and Robert John

AND

Henry Smith Williams, M. D., LL. D.

VOLUME XI

ILLUSTRATED WITH
105 DIRECT COLOR PHOTOGRAPH PRINTS PRODUCED BY A
NEW PROCESS DEVISED AND PERFECTED FOR
USE IN THESE VOLUMES

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Volume XI—By Chapters

Foreword to Volume XI

Mr. Burbank begins this, his eleventh volume, with a chapter, which, to the majority of readers, must be novel, describing, as it does, the business side of raising nut crops. He continues throughout the range of profitable nuts, discussing the paper-shell and other walnuts, the almond, the chestnut, the hickory and a miscellaneous company of other nuts—with many definite suggestions for improvement.

He tells, also, in this volume, the method employed to produce in twelve years a walnut tree such as nature takes seventy years to produce; he gives his ideas on how reforestration may be accomplished profitably; he describes each class of tree which yields us gums and syrups, and concludes with a practical chapter on trees and shrubs for shade and ornamentation, together with a number of new tree experiments which offer encouragement.

THE EDITORS.

A Dwarf Chestnut Tree

This bush-like tree is a fine example of a Burbank hybrid chestnut. The workman who stands beside the tree is five feet seven inches tall. Note the abundant crop of nuts on the tree and under the tree. Gathering chestnuts becomes a simple matter when the trees are of this type.

Nuts as a Profitable Crop

The Business Side of Nut Growing

"A CHESTNUT *bush!*" exclaimed a visitor; "that is the greatest marvel I have seen yet. I was brought up under chestnut *trees;* but when I see chestnuts growing on huckleberry bushes I am certainly having a new experience."

And I suppose this experience would be new to almost anyone who has not visited my experiment farm at Sebastopol. For, so far as I know, until very recently, there have been no chestnuts growing on bushes anywhere else in the world. But there are plenty of them in my orchard at Sebastopol; that is to say, if a sprig of a shrub only three feet or so in height and three feet across is entitled to be called a bush.

Moreover the nuts that are borne on these miniature trees are of the finest variety—large, plump nuts, at least as large as half a dozen of the nuts you are likely to find growing on chestnut

trees of the largest size; and they are sweet in flavor.

The manner of development of these anomalous dwarf chestnuts will be detailed in a later chapter. Here I refer to them only by way of introduction to suggest one of several modifications in the growing of nut bearing trees that have been brought about within recent years and that, jointly, are placing the industry of nut growing on a new basis.

If it is added that some varieties of the new chestnuts bear when only six months old, when grown from seed—rivaling corn or wheat, and seeming quite to forget the traditions of their own tribe—a further glimpse will be given of the modification that scientific plant development has wrought in the status of the nut bearing tree.

No other tree, to be sure, quite rivals the chestnut in this regard; but some of the new walnuts bear at eighteen months of age, which is quite remarkable enough. And in general the time of bearing of these nuts has been so hastened that the growing of a walnut orchard to-day is an altogether different matter from what it was a generation ago.

Moreover, a way has been found to induce the walnut tree to grow about ten times as fast as it formerly did; and the wood of the tree is of the

A Walnut Orchard

This is a California walnut orchard of forty acres, which earns nearly fifty thousand dollars a year. The trees are Persian walnuts of the variety known as Franquette, grafted on black walnut roots.

finest quality for the use of lumbermen and cabinet-makers. Of course the latter fact is of incidental interest only to the grower of nuts; yet it is not quite a negligible factor. And, from another standpoint, obviously, the wood-producing capacities of the new trees have a high degree of importance.

These and a few other transformations in the nut bearing trees, brought about by careful selective breeding, have, as I said, prepared the way for an entire change of attitude of the horticulturist toward the question of producing nuts as a business, comparable to the business of the fruit grower.

The Food Value of Nuts

Meantime there has been a marked change of attitude on the part of the medical profession, and, following them, of the general public, as to the value of nuts in the dietary.

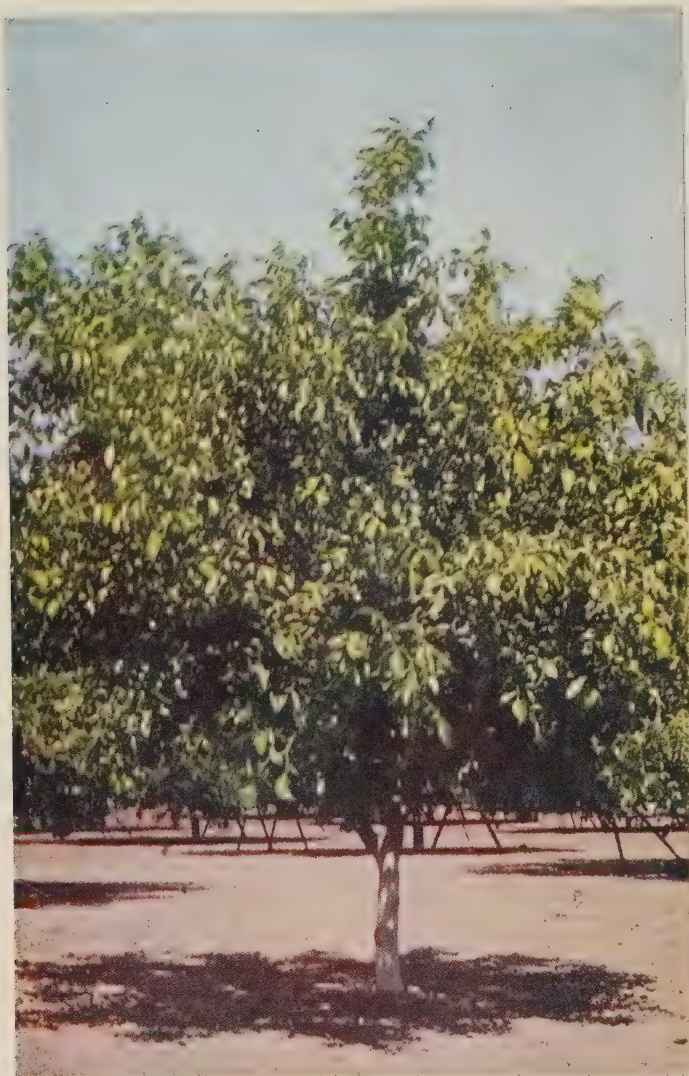
In point of fact, nuts have substantial merits as food-stuffs, and these merits are yearly coming to be more fully recognized. In the older countries, nuts have already assumed—indeed have long held—a position of economic importance, and convincing evidence of their growing recognition in America is found in the reports of experiment stations of the Agricultural Bureau, which in recent years have from time to time urged the merits

of various nuts upon the attention of agriculturists. A study of the market reports shows that nuts of many kinds are handled on a commercial scale in our cities.

There should be nothing surprising in this; for, of course, in a wide view nuts are fruits, and there is no obvious reason why they should not have dietetic value. Moreover they are for the most part grown on perennial shrubs or trees rather than on succulent and perishable annuals, and thus have close relationship with the fruits of the orchard.

But the fact that nut bearing trees for the most part receive no attention whatever from the cultivator of the soil, their product being gathered only casually, has caused them to be regarded as wild products not falling within the scope of the horticulturist. In most parts of the United States, indeed, the nut bearing trees have received no attention whatever from the cultivator of the soil, and their product has been regarded as a more or less superfluous luxury, rather than as having dietetic consequence.

In the Gulf States and in California, in recent years, there has been a radical change of attitude. In these regions the cultivation of nuts is already becoming an industry of importance. More recently, the industry has extended to New York and



A Franquette Seedling

The walnut, like most cultivated plants, cannot be depended upon to breed true from the seed. Nevertheless valuable trees are sometimes produced in this way. Here is a Franquette seedling that gives good promise, and which may have particular value for breeding experiments.

even to Canada. Meantime, the use of nuts on the table in all parts of the United States has become more and more habitual, and the shell fruits are beginning to take their proper place among the important products of the soil. Their recognition as really valuable foods is so comparatively recent, however, that it would not be superfluous to briefly run over the list of commercial nuts, with reference to their food values and their present and prospective economic importance.

Such an outline may advantageously prepare the way for the detailed account of the experimental work through which new varieties of several of the more important nuts have been developed.

The Chief Marketable Nuts

The marketable nuts include almonds, Brazil nuts, filberts, hickory nuts, pecans, Persian or English walnuts, chestnuts, butternuts, walnuts, pine nuts, peanuts, and cocoanuts, not to mention several less known and little used species.

The cocoanut, the fruit of a palm tree, is indigenous to tropical and sub-tropical regions, and may very likely have played a part in the history of developing man not unlike that ascribed to the date and the fig. It is still a most important article of diet to inhabitants of tropical islands, being prized not merely for the meat of the nut

but for the milky fluid which it secretes in large quantity. The natives sacrifice the partially ripe nut for the sake of the milk, but most northerners find this a taste to be acquired with some effort.

The meat of the ripe nut, as it comes to the northern market, is extremely palatable, and in a dried state, grated, it is widely employed to flavor sundry delicacies.

The cocoanut is raised extensively in Cuba, and to a limited extent in Florida, the total number of these nuts produced in the United States in 1899 being 145,000.

Most of the other nuts are similarly used as accessories of diet, for variety rather than as substantials. They are capable, however, of playing a more important role, as the chemical analysis of their constituents shows that they are in the main highly concentrated foods, having little waste aside from the shells. They contain all the important constituents of diet—proteins, fats, and carbohydrates—and are thus in themselves capable of sustaining life. They do not contain the various elements in proper proportion, however, to make them suitable for an exclusive diet. Moreover, their highly concentrated character makes them somewhat difficult of digestion if taken in large quantities.

The chestnut differs from the other nuts in

A Heavy Crop

This grafted Franquette walnut tree is so heavily laden that it is necessary to prop the branches to save them from breaking. Note the wide spread of the branches and the beautiful symmetry of the tree as a whole.

having a relatively high percentage of starchy matter, 42 per cent of its edible portion being found in the carbohydrate division—a proportion which no other nut except the acorn approaches. The amount of fat in the chestnut is proportionately small—only about 5½ per cent., as against the 64.4 per cent. of the English walnut and the 71.2 per cent. of the pecan.

As to protein—muscle-forming matter—the chestnut has but a little over 6 per cent., while the English walnut has 16.7 per cent., and the American black walnut and the butternut head the list with 27.6 per cent. and 27.9 per cent. respectively.

Chestnuts when fresh have a very much higher percentage of water than other nuts—no less than 45 per cent., whereas the generality of nuts have but three to five per cent.

It appears, then, that the meat of the chestnut furnishes a less concentrated food than other nuts supply, and one that is rich in digestible starches, of which it contains six or seven times the proportion common to other nuts. This excess of starchy constituents explains why the chestnut is not generally relished so much as many other nuts in the raw state. But it explains also why this nut may be eaten in large quantities when cooked.

In France and in Italy chestnuts are very generally eaten, usually being prepared by boiling,

and they constitute a really significant item in the dietary of the poorer classes. Large quantities of the nuts are also dried and ground to a flour, which keeps for some time without deteriorating, and from which sweet and nutritious cakes are made. It is said that in Korea the chestnut takes a place in the dietary not unlike that which the potato occupies with us, being used raw, boiled, roasted, or cooked with meat.

Production and Value of Nuts

Until the chestnut blight came in very recent years, threatening the entire growth of chestnut trees in the Northeastern United States, there seemed a good prospect that the cultivation of this nut would become an important industry in the near future.

Details as to the blight and the probable outcome will be considered in another connection. Meantime, there is no present indication that the other nuts indigenous to the northern parts of the United States are likely to be extensively cultivated until they have profited by the experiments of the plant developer. The thick shells of hickory nuts and butternuts, and of the native walnuts, interfere with their commercial value. We shall consider in another connection the possibility of remedying these defects, but for the moment the nuts that are grown on a commercial scale are

Paper Shell
Walnuts

These walnuts were picked before the shell had formed. The pulpy outlines of the future shell can be seen in the picture. The story of the development of the paper-shell walnut is told in the text.

solely those that will flourish in the warmer climates, and hence the industries associated with their production are confined mostly to the Gulf States and to the Pacific Coast.

To be sure, the aggregate wild nut crop of the Central and Northern States represents a considerable value. But no official estimate has been made as to the precise figures involved. In general, the nuts obtained from such trees are not looked upon as a commercial crop. They are for the most part consumed on the farm or in neighboring villages.

Only three kinds of nuts are grown on a commercial scale in the United States at the present time, these being, in the order of their productivity, the Persian or English walnut, the Pecan, and the Almond.

According to the official reports of the Census Bureau, the total nut crop reported for 1909 was 62,328,000 pounds. This was 55.7 per cent. greater than the crop reported for 1899, and the value, $4,448,000, was 128.1 per cent greater. "California is by far the most important state in the production of nuts, and Texas ranks next. No other state reported as much as $100,000 worth of nuts in 1909."

The Census Report takes note of nuts other than the three just named, but the total value of

all the others is relatively insignificant, the combined value of the Persian walnuts, pecans, and almonds, amounting to $3,981,000, or about nine-tenths of the total for all nuts.

Perhaps the most interesting feature of the report on the production of nuts is the very rapid increase in recent years. The crop of Persian or English walnuts in 1909, for example, was more than twice as great as that ten years earlier. The production of pecans in 1909 was more than three times as great as in 1899. The production of almonds, on the other hand, had decreased somewhat in the decade under consideration.

As to the actual number of trees under cultivation, the almond heads the list, the trees in bearing in 1910 numbering 1,187,962, and young trees not in bearing numbering 389,575. By far the greater number of these are in California, which has 1,166,730 almond trees in bearing, whereas Arizona, the second state, has only 6,639, and all other states combined have only 14,593. The total production of almonds in 1909 was 6,793,539 pounds, with a value of $711,970.

The almond is a native of western Asia, and has been cultivated from time immemorial. It is mentioned in the Scriptures as one of the chief products of the land of Canaan. In California it has been more or less under cultivation since about

A Comparison of Leaves

At the left, a specimen of the Franquette variety of Persian walnut; at the right a specimen of the black walnut. By hybridizing the Persian and the black walnuts, Mr. Burbank produced his remarkable Paradox walnut.

1853. The best manner of its cultivation, however, was not well understood, and the greater ease and certainty with which the walnut can be grown has led to the abandonment in recent years of many of the almond orchards.

Nevertheless the crop is one of considerable importance, as the figures just given show.

The total number of Persian or English walnut trees in bearing in 1910 numbered 914,270, of which all but about sixty thousand are in California. The rapid increase of the industry, and its prospect of still greater increase in the near future, is shown in the fact that the number of young trees, not yet of bearing age, was reported in 1910 as 806,413.

The extension of the industry is shown also in the fact that of the trees not yet in bearing no fewer than 177,004 are in the single state of Oregon, and 5,513 in Mississippi. These figures forecast the spread of industry to meet the growing demand for walnuts in America.

The total production of Persian walnuts in 1909 was 22,026,524 pounds, with a valuation of $2,297,336.

It will thus be seen that the walnut takes rank as a commercial crop of genuine importance. The value of the crop approaches that of the total crop of apricots, although not as yet approaching the

The Paper Shell on the Tree

In the course of his experiments, Mr. Burbank produced walnuts that were almost devoid of shell, but this proved a disadvantage as the birds soon learned the secret. It was necessary, therefore, to select specimens with thin shells, instead of those with no shells, to continue the experiment. The ones here shown have shells of ideal thickness.

value of the half dozen more popular orchard fruits.

The Cultivation of the Pecan

In 1899 the pecan ranked third among nut-producing trees, both as regards number of trees under cultivation and actual product. The pecan trees in bearing at that time numbered 643,292, with a net product of 3,206,850 pounds.

In the ten succeeding years the pecan industry came ahead very rapidly, and in 1910 the pecan was second to the almond as to number of trees in bearing, and second to the Persian walnut as to poundage and value of its crop. Moreover, the number of pecan trees under cultivation, but not yet of bearing age in 1910, was actually larger than the number of trees in bearing; showing a surprisingly rapid increase of the industry.

The actual number of pecan trees in bearing in 1910 was 1,619,521, and the number of young trees under cultivation 1,685,066, making a total of 3,304,587, a number in excess of the combined numbers of almond and Persian walnut trees under cultivation.

The production of pecans in 1909 was 9,890,769 pounds, with a value of $971,596. The total production of 1899 was only 3,206,850 pounds. Thus, as already noted, the production increased by more than three hundred per cent in ten years.

The Burbank Tree Baler

This is a modified saw-buck, devised by Mr. Burbank to aid in packing trees for shipment to different localities. The succeeding picture shows how the apparatus is used.

There seems every prospect that the increase will be still more rapid in the coming decade.

Peculiar interest attaches to the pecan because it is the one nut indigenous to the United States among those that at present have actual commercial importance. The pecan, indeed, must be looked to as now holding the position in the southern portions of the United States that the chestnut should occupy in the northern—that of premier nut. In recent years its merits have begun to receive wide attention, as the figures just quoted show, and the cultivation of pecan nuts for the market is likely to become a really important industry. Already there are numerous named varieties on the market, each having its champions.

These varieties have peculiar interest because of the fact that each one of them represents not an artificially developed product as in the case of most varieties of fruits and grains, but merely the progeny of an individual tree.

It appears that here and there, particularly in the state of Mississippi, there has grown a pecan tree of unknown antecedents that became locally famous for the large size and unusual quality of its fruit.

These trees, it will be understood, are all of one species, and the nuts are obviously all of one kind; no one would think of mistaking any one

of them for anything but a pecan. Yet the individuality—the personality—of each tree is revealed in the average character as to size, shape, and peculiarities of shell and kernel, of its fruit, and also as to great difference in productiveness and earliness or lateness of bearing.

The Varieties of Pecan Nuts

Of course such individuality is precisely what we have become accustomed to expect in orchard fruits and other plants under cultivation. But until recently it has not been generally understood that such diversity is commonly to be found among wild plants. So the case of the pecan furnishes an interesting illustration of the variation of plants in the wild state. The pecan trees that show these individual variations are precisely like the cultivated varieties of orchard fruits in that they do not breed true from seed. Doubtless it might be possible to develop true botanical varieties from each of them by selective breeding, but this is not necessary any more than in the case of orchard fruits. For, like other trees, the pecan may be propagated by grafting or budding.

Nothing more is necessary than to make cuttings of twigs or buds from the parent stock, grafting these as cions on an ordinary pecan stock, to produce new trees in indefinite numbers, all of which retain the precise quality of the parent.

Tree Baler in Operation

Here the young trees are being packed, with the aid of the baler, in secure bundles for shipment. It is highly important that the operation of packing should be well done, even if the trees are to be shipped only for a short distance; doubly so, of course, if they are to be sent across the continent.

Such grafts were made in the case of each of a score or so of the famous individual pecans above referred to, with the result that as many varieties have been given assured permanency. For the most part, these varieties have been named after the location where the parent tree grew, as the San Saba, the Rome; or else after the original owner of an early cultivator, as the Jewett, the Pabst, the Post, the Russell, the Stuart.

According to a recent report of the Department of Agriculture, there are ten of these varieties that have now been advertised and propagated for a sufficient time to gain wide distribution.

Extensive orchards of pecans are now under cultivation in almost all of the southern states; yet the industry is so recent that, with a single exception, the parent trees of all the ten prominent varieties are still alive and in a more or less vigorous condition of bearing.

Unfortunately the pecan is restricted as to habitat, but it flourishes as far north as St. Louis in the Mississippi Valley, in all the gulf states, including Texas, and along the south Atlantic seaboard. Texas is the chief producer (5,832,367 pounds in 1909), Oklahoma second (894,172 pounds), and Louisiana third (723,578 pounds). Quite possibly hardier varieties, which may be grown farther north, may in time be developed.

Meantime it is held with reason that within the territory to which it is naturally adapted, no other nut, native or foreign, can be considered to compete with it.

The qualities of the pecan as a desert and confectioners' nut are familiar to everyone; but the best varieties have hitherto been raised in restricted quantities, and hence have not found their way extensively into the northern markets. With the increase of the industry to commercial proportions, this defect will soon be remedied, and the pecan may be expected to advance rapidly in popular favor. But for that matter, the demand already greatly exceeds the supply.

Other Native Possibilities

Observation of the deferred recognition of the merits of the pecan suggests the inquiry as to whether there may not be other indigenous nuts that have similarly been ignored.

It may well be doubted whether there is another of comparable merit, but there is at least one neglected one that the amateur at any rate might find worthy of attention, whatever its defects from a commercial standpoint. This is the familiar hazelnut, a near relative of the European filbert. The hazel-nut is smaller than its European cousin, but it is doubtless susceptible of improvement in that regard; and the hardy nature of the

Ready for Shipment

These are bundles of young nut trees, wrapped so as to insure entire protection, being shipped by Mr. Burbank to various localities for testing under different conditions, notably with regard to hardiness. Extensive tests are often made in widely separated regions before a new variety is introduced.

shrub makes it suitable for waste lands, or as an adjunct to the chestnut orchard, even far to the north.

The hickory, the black walnut, and the butternut, already referred to as of doubtful commercial value, are nuts that may well appeal more confidently to the amateur. They grow wild in many regions of the Middle West where the chestnut is not indigenous, and the black walnut and hickory in particular are widely famed for their lumber—or were before the vandelism of the early settlers practically exhausted the supply. As to palatability, there are many persons who would be disposed to place the butternut at the very head of the list of edible nuts; and no one will deny the toothsomeness of hickories and black walnuts.

All in all, the opportunity for diversion and profit in this unexplored direction seems peculiarly inviting; and it is one that is likely to be eagerly seized by an increasing number of votaries as the years go by. The fact that nut-bearing trees add permanent beauty to the landscape gives them an additional claim on the interest of that growing body of city dwellers who are nowadays harking back to the soil for aesthetic rather than for commercial reasons. Meantime the further fact that an unfruitful tree may ultimately be valuable as lumber should make additional appeal to those

nature-lovers who, though calling themselves amateurs, like none the less to have their hobbies bring them a certain monetary return.

—In general, the nut bearing trees have received no attention whatever from the cultivator of the soil, and their product has been falsely regarded as a more or less superfluous luxury, rather than as having valuable dietetic importance.

Santa Rosa Nut Meats

In developing the Santa Rosa walnut Mr. Burbank had in mind not merely thinness of shell and abundant bearing, but also the various qualities of meat that are desirable. Among other things, he eliminated the superfluous tannin, which gives the nut a disagreeable astringency as well as brownish color. The whiteness of the meats of the Santa Rosa is evidence of his success in this regard.

The Paper-Shell and Other Walnuts

The Method Used to Produce Them

THE fact that more than 13,000 tons of walnuts are now raised annually in California, chiefly for shipment to the Eastern markets, as against 2300 tons raised in the year 1895, suggests, better than any amount of commentary, the growth of this new industry.

Part, at least, of the increased popularity of the walnut may be ascribed to the introduction of varieties having thin shells. All Persian, or so-called English, walnuts have relatively thin shells as compared with the American walnuts, but the production of the "paper-shell" varieties puts these nuts in a class quite by themselves.

And this matter of the shell is one of real significance from the standpoint of the consumer. A nut like the American walnut, which can be cracked with difficulty, requiring the use of a hammer, can never gain great popularity. The diffi-

culties encountered in extracting the meat of the nut are too great. Contrariwise, a nut that has a shell so thin that it can easily be crushed in the fingers is sure to make its way and to be found more and more generally on the dinner-table.

The terms "paper-shell" and "soft-shell" as applied to the walnut are interchangeable. There are now several varieties of walnuts on the market that are generally classified under one head or the other. Their name merely refers to the ease with which the nut can be cracked. As to this there is great variation among ordinary walnuts, and the soft-shell varieties also show a good deal of diversity. But the best varieties are so friable that they can readily be crushed in the fingers.

In point of fact, the walnut is so variable that it is possible for the plant developer to consult his own wishes in the matter of modifying its shell. I have developed a variety in which the shell became so soft that it could readily be penetrated by the bills of birds; in fact a nut that had a mere rim of shell, being thus comparable to the stoneless plum. There would be no difficulty in maintaining this variety of shell-less walnuts, but its thinness of shell was a disadvantage, and I found it desirable to breed the variety back to a somewhat thicker shell covering, by striking a compromise between the old hard-shell varieties

and a nut that was practically without a protecting shell.

One of the thin-shelled new walnuts was introduced under the name of the Santa Rosa Soft-Shell. It was produced by the usual method of selective breeding, and in producing it of course other qualities were in mind besides the thinness of shell. In particular, selection was made for early and abundant bearing, whiteness and palatability of meat, and absence of tannin—it being tannin which gives the brown color and bitter taste to the older or ordinary walnuts. The perfected Santa Rosa may be depended upon to give more than twice as large a crop as the best specimens of the France variety of walnuts, known as the Franquette.

It should be explained, however, that there are two varieties of the Santa Rosa Soft-Shell. One blooms with the ordinary walnut trees, while the other, like the Franquette, blooms two weeks later, generally escaping the frosts that sometimes affect the early bloomer. In producing the new soft-shell, I inspected nuts of the ordinary walnut from many sources. There is great variation among these nuts, and I found some that were almost entirely without shells. One seedling had nuts with the meats half exposed; that is, with shell covering a portion of its surface, suggesting the

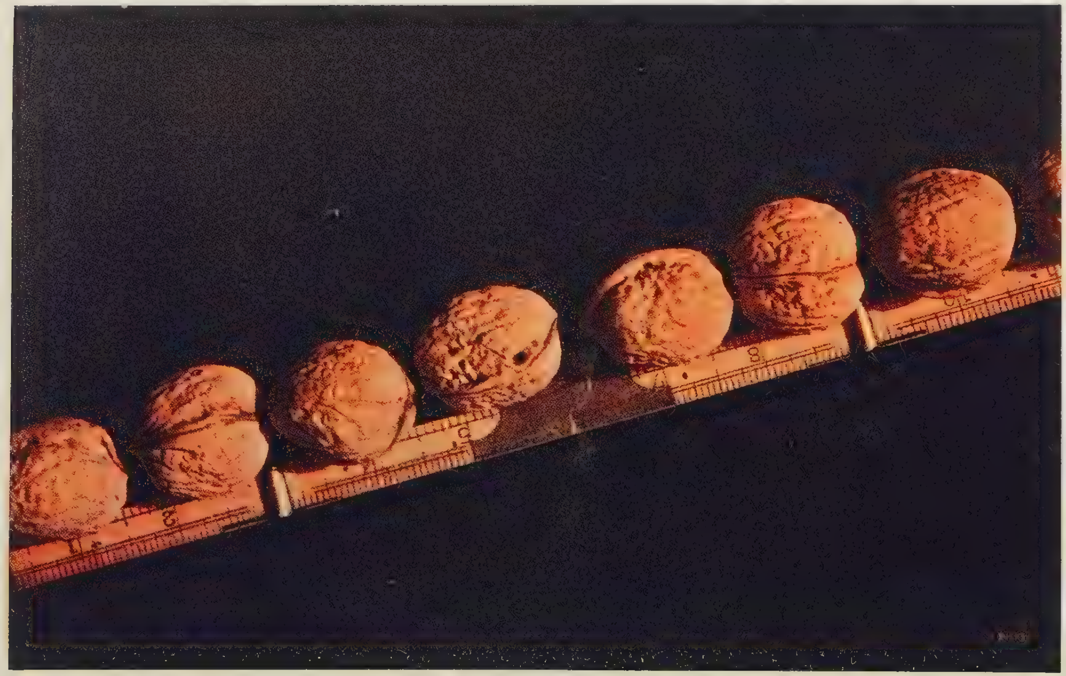
abortive stone of the little French plum from which my race of stoneless plums was developed.

By selection among the seedlings of this almost shell-less walnut, I discovered that a walnut without any shell, bearing simply a husk, could readily be produced. But, as I have just related, the birds were soon aware of my secret, and they taught me that, except for its scientific interest, the shell-less walnut had no value.

After that the experiment in walnut breeding was carried on in a different direction, a shell being obviously desirable. In due time I developed two varieties that had the shell of just the right consistency; combining this trait with the habit of early and abundant bearing and excellent quality of the nuts themselves.

Cions from these trees, grafted and regrafted, make up the race of true Santa Rosa Soft-Shells. I am informed, however, that trees grown from the seed have been extensively sold as Santa Rosa Soft-Shells, although they may depart very widely from the characteristics of the parent form. In point of fact, the name cannot be applied with propriety to any trees except those that are grown from cuttings, for the walnut is a variable tree and cannot be depended upon to come true from the seed.

The original Santa Rosa Soft-Shell, however,



A Foot of Santa Rosa Walnuts

The picture shows the large size of the Santa Rosa walnuts, and the symmetrical form and smoothness of the shell. The shell itself is so thin that it can readily be crushed in the fingers.

was grown from seed, and of course it was necessary in perfecting the varieties to grow successive generations in the same way.

The parent tree was a walnut growing in San Francisco. It bore the most valuable nuts of the kind that had even been seen in California. Mr. Alfred Wright first called my attention to this tree about twenty years ago. I found that it bore not only abundantly but regularly, and that the nuts were of exceedingly fine quality, and of relatively thin shell, their chief fault being that the two halves would sometimes separate slightly, leaving the meat exposed to the air, so that the meat did not keep as well as if in a thoroughly sealed shell.

The original tree was destroyed soon after my attention was called to it, to make room for a street, but I had secured nuts and had a colony of seedlings under inspection. Among these there was a great variation, giving me good opportunity for selection. Selection being made with reference to all the desirable qualities of the walnut, in addition to thinness of shell, I presently developed a variety that seemed worthy of introduction, and cions and trees from this were sent out under the name of the Santa Rosa Soft-Shell.

The nuts of this variety are of medium size, and they ripen about three weeks earlier than any other walnuts grown in the state. The meat is

white and most delicious of flavor. The thin shell is also white. The tree bears enormous crops, and about its only defect is that it may, on occasion, be caught by the late spring frosts. But even with this defect, it produces a larger crop of nuts than any other tree that I have seen.

Hybridizing With the Japanese Walnut

The experiments in which I hybridized the Persian Walnut with the California Black Walnut, producing the tree named the Paradox, have been outlined in an earlier chapter, and will be referred to again in a later one.

It will be recalled that this tree has extraordinary qualities of growth, but that it is almost sterile, producing only a few nuts on an entire tree, and these nuts of the poorest quality.

Another hybridizing experiment that had great interest was that in which the Persian Walnut was crossed with the Japanese walnut, known as *Juglans Sieboldii.* The Persian walnut in these crosses was used as the pistillate parent.

The first generation hybrids of this cross show a combination of qualities of the two parent species as regards the nuts, which are not borne abundantly. The foliage is much larger, however, than that of either species, the bark is white, and the tree itself is of enormously enhanced growth. It probably makes about twice as much wood in a

Trunk of the Franquette Walnut

The Franquette is a specialized variety of the Persian walnut that is particularly prized in California because of its certain bearing. Note the smooth white bark of this tree in contrast with the rough black bark of the black walnut shown in the succeeding picture.

given period as either of the parent species. The leaves are quite hairy on both sides, even more so than those of the Japanese parent. The branches are inclined to droop.

The nuts of the Japanese walnut have an exceedingly hard shell. The meat of the nut, however, is delicious, perhaps equaling that of any other nut, with the exception of some varieties of the pecan. But it is very difficult to get the meats from the shell, as they are usually broken in cracking the nut.

There is, however, a form of the Japanese walnut which is so variant that it is sometimes regarded as a distinct species, under the name of *Juglans codriformis,* but which I think not correctly entitled to this rank, inasmuch as the two forms are closely similar as to general appearance and growth. The chief difference is in the nuts, which in the *cordiformis* are usually heart-shaped, somewhat similar in appearance to the form of the central chestnut where these nuts grow three in a burr. The nut is exceedingly variable, not only in size but in form and thinness of shell. Some individual trees bear nuts that are six times as large as those borne on other trees in the neighborhood. The shell is much thinner than that of the Japanese walnut, and the meat is of the same excellent quality.

I speak thus in detail of this variety of the Japanese walnut, because its qualities are such as to merit fuller recognition than it has hitherto received. The tree is perhaps as hardy as the American black walnut; it is as easily grown, and perhaps even less particular as to soil and climate. The trees are very productive, especially as they grow older. The branches droop under the weight of the nuts. Where other walnut trees bear nuts singly or in clusters of twos or threes, the Japanese walnut tree bears long strings of nuts, sometimes thirty or more in a single cluster. The nuts are thickly set about the axils, the cluster being from six to twelve inches in length.

Hybridizing Native Walnuts

The cross between the Persian and Japanese walnuts, like that between the Persian and the California black walnut, did not result in producing a tree that had exceptional value as a nut producer. This cross, like the other, seemingly brings together strains that are too widely separated; and while there is a great accentuation of the tendency to growth, so that trees of tremendous size are produced, there is relative sterility, so that a tree sometimes bears only a few individual nuts in a season.

But the results were very strikingly different as regards the matter of bearing when the Cali-

Trunk of the Black Walnut

A comparison of this picture with the preceding ones shows the striking difference in appearance between the Persian walnut and the American species. The two were combined, it will be recalled, to produce Mr. Burbank's celebrated Paradox walnut, illustrated in other pictures of this volume.

fornia black walnut was hybridized with the black walnut from the eastern part of the United States. These two trees are more closely related species, and have diverged relatively little. Doubtless the time when they had a common ancestor is relatively recent as contrasted with the period when that common ancestor branched from the racial stem that bore the Persian and Japanese walnuts.

Yet the differences between the walnuts of the eastern and western parts of America are sufficient to introduce a very strong tendency to variation.

Indeed, the result of crossing these species was in some respects scarcely less remarkable than that due to the crossing of the Persian walnut with the black walnut of California.

In this case, as in the other, the hybrid tree proved to have extraordinary capacity for growth. Indeed, I have never been able to decide as to which of the hybrids is the more rapid grower. But in the matter of nut production, the discrepancy was nothing less than startling. For, whereas the first-generation paradox walnut produced, as we have seen, only occasional nuts, the hybrid between the two black walnuts—it was named the Royal—proved perhaps the most productive nut tree ever seen.

I have elsewhere cited a tree, sixteen years of age, that produced twenty large apple boxes full

of the nuts in a season—so extensive a crop that I sold more than $500 worth of nuts from this single tree that year. And the following year I sold nuts from another tree to the value of $1,050. The nuts were used for seed to produce trees of the same variety.

This extraordinary difference between the two hybrids is doubtless to be explained by the slightly closer affinity between the parents of the Royal. Their relationship chanced to be precisely close enough to introduce the greatest possible vigor and the largest tendency to variation compatible with fertility. The parents of the Paradox, on the other hand, were removed one stage farther from each other, permitting the production of offspring of vigorous growth, but bringing them near to the condition of infecundity. They were not absolutely sterile, but their fecundity was of a very low order.

The seedlings of the Royal hybrid vary in the second generation, as might be expected, although the variation in size and foliage is less than in the case of the Paradox. The extraordinary range of size, some of the second generation hybrids being giants and others dwarfs, has been elsewhere referred to. It will be recalled that some of these second generation hybrids grew to the height of four feet in the first year, while beside them were

A Grafted Walnut Tree

The selected varieties of walnuts do not breed true from the seeds; so it is necessary to graft them, in making commercial orchards, just as in the case of the orchard fruits. Here is a typical grafted specimen, growing in the back yard of Mr. Burbank's home in Santa Rosa.

others that grow only six or eight inches. One grew five hundred times as fast as another, the nuts from which they grew having been picked from the same tree, and planted the same day side by side.

To make sure of securing trees having the traits of the original Royal, it is necessary to grow the trees from grafts either of the first generation hybrid or a selected second generation hybrid showing rapid growth. The number of the latter, however, is sufficient to ensure a reasonable proportion of good trees from any lot of seed; and the Royal has been in general demand as a tree to furnish stocks on which the Persian walnut may be grafted.

It is found that on most soils a Persian walnut grafted on roots of the Royal hybrid will produce several times as large a crop as if on its own roots. Moreover the trees under these conditions are relatively free from the blight.

The nuts of the Royal hybrid are similar to those of the parents, except that they are larger in size. The very thick shell is objectionable, as already noted. Doubtless the shell can be made thinner by selective breeding, but no comprehensive efforts in this direction have as yet been carried out. The black walnut, in spite of the really fine quality of its nut, has never become an impor-

Parents and Offspring

At the right, a specimen of the Persian or English walnut; at the left, a specimen of the Japanese walnut, known as Juglans Seyboldi; in the center, a Burbank hybrid between these two species. It will be seen that the hybrid is much larger than either parent, and that it shows qualities of each, following the Persian parent in its general appearance, and the Japanese parent in the form of the shell.

tant article of commerce. But there are great possibilities open to it if the shell could be reduced to a condition comparable to that of the English walnut.

The nuts borne by the Paradox are intermediate in form and appearance between the types of nuts of its parents. Exteriorly they resemble the Persian walnut, but the shell partakes of the thickness and solidarity of that of the black walnut. In at least two instances among the thousands of second generation Paradox walnut trees that have been grown, the trees produce extra large fine walnuts in abundance. However, both of these are quite thick-shelled, but from their second generation hybrid, which can be multiplied abundantly, good, hardy, thin-shelled varieties may be produced.

It is possible that further hybridizations, in which the Royal and Paradox hybrids were themselves crossed, might result in the development of a variety, properly selected, that would retain the good qualities of the Persian nut, and combine these with the size and prolific bearing of the Royal.

Hybridizing Methods

The experiment, at any rate, is well worth trying. But, of course, whoever undertakes it must be content to make haste slowly, for the black wal-

nut has not as yet been made to bear in childhood, so to speak, as the chestnuts and some strains of the English walnut now do. But in this regard also there would doubtless be rapid improvement under selection.

The actual method of hand-pollenizing is very simple. Nothing more is necessary than to break off the flower bearing branch, just at the right time, and shake it over the flowers of the pistillate parent.

Of course one cannot make sure that some of the flowers will not be self-fertilized, but by planting a large number of the nuts, it will be possible to determine from the appearance of the seedlings which ones are hybrids. Also where the trees grow close together, there are sometimes natural hybrids, though I was not aware of this when I made my first experiments, in years 1875-1880.

When I made my first experiments at hybridizing the walnuts, I planted the seeds of the entire tree. In the rows of seedlings, I could at once determine which ones were hybridized, as these grew far more rapidly than the others, besides differing notably in general appearance.

My first experiment was made with two black walnuts, and it was the success of this that led me to attempt to hybridize the Persian and California walnuts the following year. The hybridization in

Hybrid Walnuts

In Mr. Burbank's catalogue of 1894, a picture was given of the first nuts ever borne by the Paradox walnut, his celebrated hybrid between the Persian walnut and the California black walnut. "These nuts," he said, "as would be expected, are a complete combination of the two species in every respect; one was tested, the others planted, and variations are now in order." The variations appeared in due course, as this picture, showing the fruit of later generations, amply testifies.

which the Japanese walnut was used was made a few seasons later. The results, as regards the production of nuts, have been sufficiently detailed. Up to the present no variety of commercial value as a nut bearer has been produced, although the indirect influence of the hybrids on the Persian walnut industry, through their use as stocks, has been quite notable.

The Butternuts

There is a very near relative of the black walnut, known as the butternut, that was formerly well-known in most forest regions of the eastern United States.

The two trees are of closely similar appearance, and the nuts have the same characteristic thick and corrugated shell. The butternut, however, is oval in shape, whereas the walnut is nearly round. The meat of the butternut is also somewhat richer in quality, and it is generally regarded as superior in flavor. The meat itself, indeed, is by many people regarded as superior to that of any other nut. The difficulty is that the shell, like that of the black walnut, is very thick, making it difficult to extract the meat without breaking it.

The butternut thrives generally where the black walnut does. It makes a more spreading tree, but the wood is softer and far inferior for cabinet purposes.

There is an Asiatic species, known as *Juglans Manschurica,* that may be regarded as intermediate in form between the butternut and the black walnut. It rather closely resembles the Japanese walnut in general appearance, but it bears a nut with rough surface like the butternut, and the meat is also similar in quality and appearance to that of the butternut, being superior to that of the black walnut.

This tree may be said to form a connecting link between the Japanese walnut, the American black walnut, and the butternut. Possibly it could be used advantageously in a hybridizing experiment that would ultimately blend the strains of these different species.

The Cultivation of the Walnuts

The idea of growing walnuts commercially is one that has scarcely been thought of in the temperate regions of the United States. Even in regions of the middle and eastern states where the English walnut will grow, it has never been cultivated extensively, and of course this tree is too tender to be profitably grown in the northern states. But the black walnut and butternut, on the other hand, are exceedingly hardy trees, thriving even in regions where the winters are excessively cold.

All of these trees, however, require a deep, rich,

More Hybrid Walnuts

The nut of the Paradox walnut has the outward appearance of the Persian walnut, one of its parents. The shell retains, however, a good deal of the thickness of the black walnut, bu this can doubtless be modified by selective breeding in later generations.

moist, loamy soil, in order to thrive. Trees that produce wood of such extraordinary hardness of texture, and nuts so stocked with fats and proteins, could not be expected to draw adequate nourishment from impoverished soil. In point of fact, the black walnut and the butternut, in the regions of the United States to which they are indigenous, are usually found growing along the rivers, or in rich alluvial valleys. Any idea that they could be raised to advantage on soil that is too poor to produce ordinary crops of cereals or vegetables, is fallacious.

At the moment, there is not demand enough for the black walnut or the butternut to justify the raising of these trees on a commercial scale. It will be necessary to produce new varieties by hybridization and selective breeding before these nuts can be made popular. But, as I said before, there is every reason to believe that a series of experiments looking to the production of improved varieties would be more than justified by the results obtained, and I shall point out in another connection the commercial possibilities of producing lumber trees in this way that make the project doubly attractive.

It may be well to call attention to one or two peculiarities of the walnut that should be known to anyone that attempts hybridizing experiments.

In particular it should be understood that the staminate flowers of the walnut usually bloom and shed their pollen from one to four weeks before the fruit-bearing nutlets appear.

One would naturally suppose, under these circumstances, that the pollen would all be lost and that there could be no crop. But, in point of fact, the pollen appears to retain its vitality for a long time, and even where it has been shed some weeks before the ripening of the pistillate flowers, there may be a full crop. The hand-pollenizer must bear in mind this tendency of the two types of walnuts to mature their flowers at different times. Still, as already suggested, the pollen appears to retain its vitality, and ultimately to be able to effect fertilization even though applied some time before the maturation of the pistils.

In France the early spring frosts are likely to be very destructive to the ordinary walnuts, and the French nut raisers have come to depend largely on the Franquette, a variety already referred to. While this variety is in some respects inferior, it has the one supreme quality of not blossoming until the season of spring frosts is over. It blooms perhaps four weeks later than ordinary varieties. This ensures a good crop from the Franquette variety, even in years when others have been damaged by the frost, so that the average production

Effects of the Walnut Blight

In some seasons the walnut suffers from a blight that very seriously injures the crop. The picture shows samples of nuts ruined by the blight in a recent year. Mr. Burbank's selective experiments, as the reader is aware, are always conducted with an eye to producing varieties that are relatively immune to the attacks of fungous pests. Such specimens as these would obviously be avoided in all breeding experiments.

of this variety throughout a term of years may be higher than that of others that in any given season may surpass it.

There is obvious opportunity to hybridize this variety with the other varieties of the Persian walnut that blossom earlier, but produce a better crop of nuts. Such crossing would doubtless supply material from which races may be developed that will retain the late blossoming habit of the Franquette, combined with the nut producing qualities of the other parent.

We have seen that a tendency to fruit late in the season is usually correlative to a tendency to early ripening of fruit so that late bloomers are adapted to growth relatively far to the north. A late blooming strain of the Franquette walnut might furnish material for the development of a variety of walnuts that will be hardy enough to grow in higher altitudes than those to which the English walnut is now limited. But for the production of real hardy races it is probable that hybridizing with the black walnut—the same cross that produced the Paradox—must be looked to, to supply the foundation for a series of experiments in selective breeding.

The pioneer work, indeed, has been done in the production of the Paradox walnut itself.

It may reasonably be supposed that further

experiments in which this hybrid is used as a parent will lead to the development of altogether new races of nuts that will have economic importance.

The entire matter of the development of commercial nuts has only recently begun to attract the attention of the orchardists. There is reason to expect that the developments of the next few generations will be comparable to the progress of the past century in the development of orchard fruits.

—The edible nuts are destined to occupy a far more important place in the dietary than they have ever had before, at all events in the temperate zone. And the walnut is in the van of the new movement.

Almond Tree in Blossom

One great fault of the almond tree is that it tends to blossom so early in the season that its flowers are likely to be blighted by the frosts. This makes it impossible to raise almonds commercially in many regions where they otherwise would thrive. Careful selective breeding will probably overcome the defect.

The Almond and Its Improvement

Can It Be Grown Inside of the Peach?

IN the early years of my experimenting, soon after I began importing plants, I attempted to cross the Japanese plum with the almond.

The cross was made without very great difficulty, and the results were exceedingly interesting. Each species was fertilized with the pollen of the other, and here as elsewhere it appeared to make no particular difference in which way the cross was made.

The hybrid seedlings partook somewhat of the character of the earliest of the hybrids produced by crossing the plum and the apricot. Most of the seedlings outgrew either parent, their enhanced vigor suggesting that of the hybrid walnuts. But on the other hand some of them almost refused to grow at all, being permanently dwarfed, and in this regard suggesting a certain number of the second generation of the walnut hybrids.

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This wide diversity of form and vigor in the first generation hybrids is a rather unusual phenomenon. As a rule, we have observed that first generation hybrids are somewhat uniform in character, and that the tendency to wide diversity appears in the second generation. Indeed, attention has more than once been called to the fact that the discovery that such is the tendency among hybrids was the one that put me on the track of most of my successful plant developments.

At the time when my experiments in hybridizing the Japanese plum and the almond were commenced, there were few, if any, other plant experimenters anywhere in the world who seemed fully to grasp the principle that variation occurs in the second generation, and that it is by raising large numbers of second generation hybrids from which to make selection, that the development of new and useful varieties of plants may best and most rapidly be carried out.

This principle is so familiar to-day that horticulturists and botanists who refer to it very commonly overlook the fact that the recognition of the principle is very recent.

Twenty-five years ago I found it impossible to convince most well known horticulturists and botanists and biologists—with many of whom I had some spirited discussions on the subject—that the

Two Almonds, One Showing the Nectarine Color

The almond and the nectarine are very readily hybridized. Indeed, they are constantly crossed by the bees wherever they blossom at the same time in the same neighborhood. Here is a specimen that reveals its hybrid origin in the form and color of its fruit.

great individual variations occur in the second and a few succeeding generations.

To-day all these men, in common with horticulturists and biologists in general, acknowledge that these variations and recombinations do occur. Indeed, nothing more is necessary than the most casual inspection of the new varieties that have been developed at Santa Rosa in the intervening period to establish the validity of what was generally regarded as an heretical view only twenty-five years ago.

And yet the case of the first generation hybrids between the Japanese plum and the European almond, showing the wide diversity just recorded, suggests that it is not always easy to lay down rules of thumb. Observation of the phenomenon of plant development in the field may present complexities that make the sifting out of principles difficult. No one whose first hybridizing experiments happened to be performed with chance hybrids of the plum and almond, and who saw among his first generation seedlings all the range of forms from dwarfs to giants, would have been likely to conclude that the first generation hybrids are generally uniform in character and that variation takes place in the second generation.

Looking back now, and being able to check the observation with knowledge gained through not-

Almonds on the Stem

The picture suggests the tough leathery character of the seed-covering that makes us the almond fruit. Unlike its allied stone fruits, the almond has been selected for the seed itself, not for the pulp that surrounds it. Mr. Burbank has shown that the pulp may also be made attractive through hybridizing and selection, as we shall see.

ing the effect of hybridizing hundreds of other species, it is interesting to make inquiry as to why the first generation hybrids of the plum and almond showed such anomalous diversity.

I am inclined to think that the answer may be found in the assumption that either one parent or the other was itself a hybrid. Perhaps both parents were hybrids. The fact that almonds are known to cross with the peach and the nectarine—to which reference will be made more at length presently—lends color to this assumption. And of course there is no question that the Japanese plums are largely hybridized. In a word, then, the hybrids produced by cross-pollenizing the Japanese plum and the almond were probably in reality second generation hybrids having the strains of other species than the almond and the Japanese plum in their veins.

Be this as it may, the facts as to the curious diversity among the plum-almond hybrids have more than passing interest.

It should further be recorded that the diversity in size was matched by the wide range of diversity in minor characteristics. The bark and leaves varied extensively among the different hybrids; on some trees the buds were round and plump, and on others long and sharp. Many of the trees produced somewhat abundant blossoms, and the

individual blossoms varied widely in color and in size.

But there were other trees that produced no blossoms whatever under any circumstances.

These would form great clusters of buds, but instead of bursting into flowers the buds would drop off and ordinary branches would come out in their stead.

In the case of buds already opened to form flowers, the blossoms not only varied as to size and color, but they showed the most astonishing diversity as to their essential fructifying organs. Some of the blossoms had numerous pistils and no stamens. Others had numerous stamens and no pistils. In yet other cases there were blossoms having stamens and pistils but absolutely without petals.

In no case was fruit formed. The blossoms one and all were sterile.

An attempt was made to fructify the blossoms by pollenizing them with pollen from each of the parents. But the effort was futile. The ovaries were seemingly incapable of maturing.

It would appear, then, that the Japanese plum and the almond, as represented by the particular specimens that were used in these hybridizing experiments, were just at the limits of affinity that permitted cross-fertilization, but imposed sterility

Selected Almonds

It has been suggested, not without plausibility, that the almond represents somewhat closely the primitive type of stone fruit, from which all our other stone fruits have been developed. Be that as it may, the leathery covering of the present-day almond is something strikingly different from the pulp of the peach or plum or apricot.

on the offspring. The parents were a shade more widely removed from each other genetically than were, for example, the plum and the apricot or the Persian and California walnuts.

Conceivably this fact, and not the mixed ancestry of either parent, may have accounted for the diversity of form of the progeny.

As the plum-almond hybrids were sterile, it is obvious that the experiments through which I had hoped to develop new varieties and perhaps new species of fruits could go no further in this direction. It is of course possible that individual plums and almonds or different varieties of the two races might be found that would combine to produce fertile offspring. This supposition finds support in the fact that my earliest crosses between the plum and the apricot were also sterile; whereas later ones produced the fertile plumcot, as the reader is aware.

So it is obviously worth while to continue the experiments of hybridizing the plum and the almond, and there is every reason to hope that interesting and valuable results may be attained.

My own experiments, however, although they have been repeated occasionally and have never been quite lost sight of during the twenty-five years that have intervened since the first tests were made, have produced only the anomalous results

just related. Yet even these, in addition to their scientific interest, may be thought to point the way to more practical developments.

At least they prove that there is no barrier between the tribe of plums and the tribe of almonds that may not be partially broken down.

The Almond Crossed With Peach and Nectarine

Since the almond can be crossed with the plum it may reasonably be expected that mating would be effected with its closer relatives, the nectarine and peach, with even greater facility.

And in point of fact it has been observed that the almond crosses with the nectarine so readily that it is practically impossible to prevent cross-fertilization when the two trees grow in the same neighborhood. The bees appear to visit them indiscriminately, and to effect hybridization so commonly that it is impossible to raise fruit from the seed with any degree of certainty when there has been an opportunity for cross-fertilization. The same thing is true, as might be expected, of the peach; which, indeed, as we have elsewhere seen, is scarcely separable botanically from the nectarine.

Most varieties of almond blossom very early in the season, before nectarines or peaches are in bloom. But where the trees are blossoming at the same time in the same neighborhood the bees are almost certain to mix them indiscriminately.

Another Group of Almond Fruit

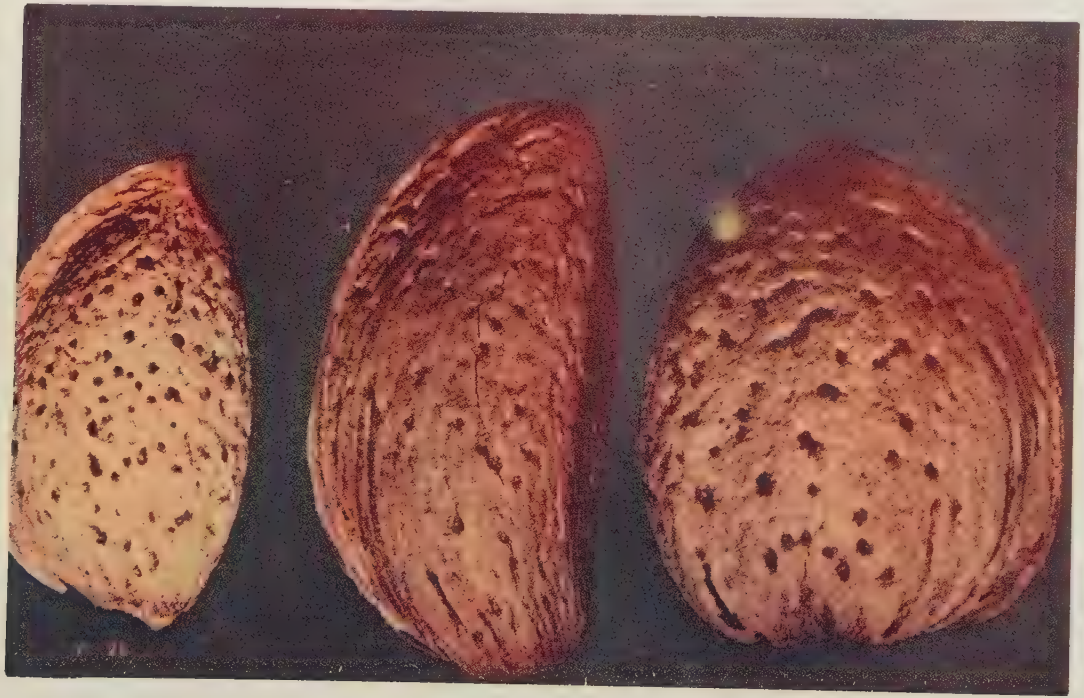
Although the almond is so different as to texture of its pulp from the other stone fruits, yet the relationship is obvious even to casual observation. If proof of this relationship were needed, it is furnished by the results of hybridizing experiments, which give most interesting specimens, variously combining the qualities of almond and of peach or nectarine.

It is nothing unusual in California where almonds and peaches are growing in the same orchard, and where peach seeds are planted, to have one third of the seedlings turn out to show marked characteristics of the almond; or, contrariwise, to find that a number of the almond seedlings show the characteristics of the peach.

This, of course, is sometimes annoying to the practical orchardist, but it suggests interesting possibilities for the plant developer.

Wishing to see just where the experiments might lead, I have crossed the almond with the nectarine, using great care to make sure that the experiment was not vitiated by accidental pollenizing. In some cases I have used the old method of tying a sack over the flower, which I do not usually consider necessary in pollenizing if properly performed.

Hybridizing experiments of this type have been carried on somewhat extensively for at least fifteen years. I have thus produced a hybrid almond-nectarine that has an absolutely smooth skin, with nothing of the roughness and comatose condition usually found in the almond. The hybrid reproduced the color and quality of the flesh of the white nectarine parent as well as its smooth skin. And as the almond quality of seed and stone was fairly reproduced, the combination



Some Mammoth Specimens

At the left, a selected specimen of the common almond; in the center, the Palestine almond; at the right a specimen of the "big fat" almond,—the latter obviously well named. Note the characteristic texture of the shell, which does not vary greatly in these specimens, but which differs markedly from that of all other stone fruits.

was a very curious one—to all intents and purposes a smooth-skinned peach, with white flesh, bearing at its core an almond nut.

Further experiments in selective breeding will be necessary to develop the hybrid to a stage at which its qualities of flesh and nut respectively will give it commercial importance; but the foundation for such development is supplied in the hybrid already secured. This hybrid, it may be noted incidentally, is a most remarkably vigorous grower.

An allied series of experiments of equal interest was inaugurated by hybridizing the Languedoc almond and the Muir peach, using, as in the other case, the utmost precaution to prevent foreign pollenization.

Many seedlings were grown from this cross and a large number of them have been under observation for years.

The most notable thing about these hybrid seedlings from the outset was the tendency of many of them to take on rapid growth. Some of them grow five or ten times as fast as the average seedlings of either parent. This propensity of hybrids to rapid growth is something that we have seen manifested in many other cases. It is, indeed, a rather common result when species that vary by just the right amount are hybridized. The hybrid

Meats of Selected Almonds

These are the meats of the almonds shown in the preceding picture, arranged in the same order, with the common almond at the left and the Palestine almond in the center. Although these almond meats differ so radically in form, it will be seen that they retain the characteristic almond quality throughout, just as we saw in the case of the shells in the preceding picture.

walnuts furnished the typical illustration of this on the most spectacular scale.

The fruit of these almond-peach hybrids varied a good deal on different trees. Sometimes the fruit was leathery like that of the almond, but in other cases it was edible and quite peach-like. In a few cases the pulp was so fully developed that it might be considered a fairly good peach. The seed covering was usually in the shape of an almond and smoother, thinner, and generally more elongated than the peach stone. It was hard-shelled and corrugated, but had not the texture of the peach stone. The meat within was sweet or slightly bitter, suggesting a rather inferior almond.

Thus the fruit of this hybrid might be said to be fairly intermediate between the fruits of the parents, yet on the whole the flesh of the peach and the stone of the almond, respectively, tended to be prepotent. This is what would perhaps be expected, when we recall that the flesh is the specialized modern development in the case of the peach, and that the seed is similarly specialized and developed in the case of the almond.

We have found occasion to believe that prepotency or dominance is conditioned on newness of development; the case of the peach-almond hybrid gives a measure of support to this theory.

Variations in Seedling Almonds

Like the other cultivated orchard fruits, the almond does not breed true from the seed. If the crop is to be kept uniform, the orchard must be grafted. Interesting variations may result, however, from growing the seedlings, as this picture suggests. Here is material for the development of any number of varieties.

But while the specific qualities of peach and almond, representing their specialized development in comparatively recent times, thus tend to be segregated along Mendelian lines, yet the traits in each case are of such long standing that they do not Mendelize in the clear and satisfactory way that we have seen manifested in some other cases —for example, the color of the blackberry, and its thorns.

There is, to be sure, a very marked segregation in the second generation, illustrated by the most astonishing variation among different second generation hybrids in the matter of size, rapidity of growth, and almost every quality of flower and fruit.

This variation was so marked, indeed, as to rob the seedlings of the value they might otherwise have had as stock for grafting. The large-growing specimens have value for this purpose, but the diversity among the seedlings is so great that they cannot at present advantageously be grown with any hope of producing dependable stocks.

In the matter of the fruit, the second generation hybrids are equally variable. There are some specimens that tend to reproduce the almond quality and others that tend to reproduce the peach quality. And as might be expected there are yet

The Almond and Its Cousin

Here, reading from left to right, are shown the peach, the almond, and the nectarine. The peach and nectarine are regarded as variant examples of the same species. The almond crosses readily with either, producing interesting hybrids.

others that combine the quality of the two fruits. The best of these bear fruits that are obviously peaches, even peaches of fair qualities, yet that have at their center what would be at once recognized as an almond nut, with characteristic shell and seed.

In a word, these are almonds grown inside the peach—a combination of obvious interest.

But this anomalous fruit, notwithstanding its interest, did not present commercial possibilities that could at the moment be realized. The peaches that thus bear almonds are not of the best quality as compared with recognized varieties of commercial peaches. Neither, on the other hand, were the almonds borne by these peaches of a quality to enable them to compete in the market with the best varieties of commercial almonds.

What had been produced, in a word, was a rather inferior peach bearing at its core a rather inferior almond. The combination has obvious scientific interest, but it has no immediate commercial value.

There is no reason to doubt that a continuance of the experiment in which selection was made among the best specimens of this hybrid fruit, together with further hybridization in which the strains of the best peaches and the best almonds were successively introduced, might result in pro-

Seeds of Peach, Nectarines, and Almond

The picture shows the stone of the nectarine at the left, two peach stones in the center, and the almond stone at the right. Note the thin shell of the latter in comparison with the former. Doubtless the difference is due to selective breeding through countless generations.

ducing a peach-almond that would have flesh equal to the best varieties of peaches and a nut equal to the best almonds.

Even now there are apricots that bear delicious nuts. Inasmuch as the apricot is already in this condition, there is no reason why the peach should not do the same. The apricot seeds of California are now nearly all shipped to France to make almond oil.

At the time when the experiments above referred to were carried out, however, it was not clear that a fruit combining the qualities of the peach and the almond would have great commercial value. The peach industry and the almond industry are so entirely different that the inauguration of altogether new methods would be necessary to make them operable in combination.

Hence the hybridizing experiments were not carried beyond the second generation, and the hybrid trees were thereafter used as stocks for the engrafting of cions that gave greater commercial promise, even though less interesting from a scientific standpoint.

A New Peach-Almond Cross

A subsequent series of experiments was undertaken, however, to which reference has been made in another connection, in which the almond was combined with the purple-leafed peach.

Structure of the Almond

The picture at the left shows a cross-section of the almond, revealing the relative thickness of pulp and shell and meat. At the right, the thin shell has been cut away, and the meat extracted. Mr. Burbank suggests the desirability of breeding experiments to produce almonds having white stones to avoid the necessity for bleaching.

It has already been recorded that the first generation hybrids of this cross bore green leaves exclusively, but that purple leaves appeared in a certain proportion of the hybrids of the second and subsequent generation.

In this cross, the purple-leafed peach was used invariably as the pistillate parent. There is every reason to suppose, however, that the results would have been the same had the cross been made the other way.

Among the second generation seedlings were not only some with red leaves, but others that showed a combination of colors varying from the pure green almond leaves through different shades to the crimson leaf of the peach.

There was thus exhibited a pronounced tendency to segregation of colors in certain cases, and a combination of the colors in others.

Selection being made among the trees with the purple leaves, this characteristic, as might have been expected, reproduced itself, and a race of purple-leafed peach-almonds was developed. The fruit of this hybrid is purple fleshed, and as to its general characteristics it is a fair compromise between the peach and the almond, not unlike the hybrid form already described.

This form of peach-almond has considerable merit as an ornamental tree, and it will probably

Leaves of a Peach-Almond Cross

Mr. Burbank has experimented extensively in hybridizing the almond and the peach as well as the nectarines. The hybrids, particularly in the second and later generations, show all manner of variations, some of them combining the qualities of both parents in a very striking way, others reverting strongly in one direction or the other. The spray of leaves here shown manifests the influence of both parents.

prove of value as an acquisition for the garden and dooryard. Even though a peach that bears an edible seed has no greatly added commercial value, owing to the small size of the seed, such a fruit with large seed of thinner shell, and with peach flavor, should certainly be appreciated.

Improving the Almond

All this has to do with the production of a compound fruit in which the almond seed is only an accessory. It remains to say a few words about the almond itself as a commercial nut.

The importance of the subject will be obvious when we record that in a recent year more than three thousand tons of almonds were produced in California alone. When it is further recalled that numberless unsuccessful attempts have been made to establish almond orchards in various warmer regions of the United States, and that the failure of these orchards has been due almost exclusively to a single remedial defect, the importance of the almond from the standpoint of the plant developer will be more clearly understood.

The one great defect of most varieties of almond is that they bloom so early that their blossoms are likely to be destroyed by frost. A second minor defect is that many of the varieties of almond do not bear well unless they are cross-fertilized with pollen from other varieties.

A Peach-Almond Hybrid

In this specimen the fibrous covering of the stone is increased in strength, as the picture suggests. It would seem as if hybridization had accentuated the almond quality, without introducing any tangible quality of the peach. There are other specimens, however, in which the fleshy covering is juicy and peach-like.

The later defect is obviously one that requires only reasonable intelligence in the planting of different varieties in contiguous rows, so that cross-fertilization may readily take place, or the production of varieties with perfect blossoms. To overcome the defects due to too early blooming is a somewhat more difficult matter.

Fortunately, however, there is a rather wide range of variation among different kinds of almond as to the matter of time of blooming. It follows that there should be no great difficulty in producing, by selective breeding, a variety that combines desirable qualities of nut production with the habit of late blooming. The difficulty has been that until recently orchardists have not recognized the possibility of thus segregating and recombining characters, and they have "trusted to luck" in setting out their almond orchards, so in a large number of cases the profitless trees were cut down or regrafted to Burbank prunes.

Latterly, the California orchardists have learned that there are two or three varieties that may be depended on, notably the Nonpareil and the Ne Plus Ultra, both of which originated in California from seedlings grown by A. T. Hatch of Salinas County. These may best be polenized, in the opinion of experienced orchardists, by the variety known as Texas Prolific.

Unfortunately neither of the varieties mentioned produces nuts of the largest size, but their certainty of bearing gives them advantage over varieties that would otherwise be superior but which cannot be depended upon.

It should not be difficult, except that such an experiment necessarily takes time, to crossbreed the different varieties that have individual traits of exceptional value, and thus to produce in the second generation, or through successive selections, varieties that will combine the best qualities. Indeed, something has already been accomplished in this direction, notably in the case of such a variety as that known as Drake's Seedling, a late blooming variety that is prolific and a regular and abundant bearer, notwithstanding its parent form was the Languedoc which has been pretty generally condemned for irregular bearing. There is no good reason why the almond should not bear as regularly and as abundantly as the apple or peach or cherry.

As to the shell of the almond, this has been so specialized through selective breeding that in the best varieties it is perhaps as soft and thin as desirable. If it becomes too soft, it is liable to injury in shipping, and thus the appearance of the nuts is marred and their market value impaired; also being subject to destruction by birds before

Almonds Grown in Peaches

These are the stones of various types of peach-almond hybrids. It will be seen that some of them show the characteristic appearance of the peach stone, where others show the marked influence of almond parents. All of them bear meats that have the characteristic almond quality, more or less modified.

it is harvested. Perhaps, however, selective breeding may advantageously be carried out with an eye to the whitening of the shell of the nut. At present it is necessary to bleach the shells after the nuts are thoroughly dried, first with low pressure steam and then with the fumes of sulphur. Such bleaching is necessary to meet the demands of the consumers.

It would obviously cheapen production and save a good deal of trouble if a variety could be produced that would have the desired color of shell in the natural state. Another defect is that the almond tends to cling to the tree too tenaciously, requiring unnecessary labor. Any almond grower would appreciate these two experiments.

My own experiments of late have been in all the directions mentioned, and I have reason to suppose that I now have better almonds than any heretofore grown.

It is clear, then, that there are various directions in which the almond may profit by the attentions of the plant developer. The steady and increasing demand for this nut warrants the expectation that systematic efforts for its improvement may meet with an adequate financial reward. Already the cultivation of the almond is an industry that exceeds in importance that of any other nut except the walnut and pecan. And it is an

industry that will increase in proportion as the efforts of the plant developer make the almond a more certain bearer. What has just been said will sufficiently indicate the lines along which the plant developer must work in order to produce these results.

—It is obviously worth while to continue the experiments of hybridizing the plum and almond, and there is every reason to believe that interesting and valuable results may be attained.

The Chestnut—Bearing Nuts at Six Months

A Tree Which Responds to Education

When a boy in Massachusetts, I used to observe the great variation among the native American chestnuts in my father's wood lots. Like most boys I was fond of nuts, and in gathering them I soon learned that there were certain trees that bore large, glossy, rich brown nuts with sweet toothsome meats, and that there were other trees that bore only small, flat, ash-colored nuts of insignificant size and inferior quality.

I observed that the trees that bore these seemingly quite different nuts differed also in size and in foliage. And I particularly noted that such variations were not seemingly due to any local conditions, inasmuch as the trees bearing fine nuts and those bearing poor ones might stand side by side.

I noted similar variations regarding a good

many other trees and plants of various kinds. But I recall that the variations among the chestnuts, and also among hickories and shell-barks, made a very vivid impression on my mind. It seemed strange that trees obviously of the same kind should show such diversity as to their fruit.

When, at a later period, I began my experiments in California, I recalled the variable chestnuts, and it occurred to me that a plant showing such inherent tendency to vary should afford an unusual opportunity for development—for by this time I had come to appreciate the value of variation as the foundation for the operations of the plant experimenter.

But I had conceived the idea also—as our earlier studies have shown—that there would be very great advantage in hybridizing the best native species of plants with plants of foreign origin. And I had the chestnuts in mind among others when I sent to Japan and Italy and the eastern states for new plants with which to operate. So the very first lot of plants that came to me from Japan (in November, 1884), included twenty-five nuts that I find listed in a memorandum as "monster" chestnuts. The same shipment, it may be of interest to recall, included loquats and persimmons with which some interesting experiments were made; pears, peaches, and plums of which

Six Months Old Chestnut Tree in Bearing

This is a veritable infant prodigy. Only six months ago, its cotyledons broke the soil; and to-day it bears goodly clusters of maturing fruit, as the picture shows. To cause a tree to take on this habit of an annual plant is a remarkable triumph of selective breeding.

the reader has already heard; and climbing blackberries and yellow and red fruited raspberries that had a share in the development of some fruits that presently attained commercial importance.

But perhaps there was nothing in the entire consignment that was destined to produce seedlings with more interesting possibilities of development than the 25 "monster" chestnuts. For the hereditary factors that these nuts bore were to have an important influence in developing new races of chestnuts of strange habits of growth—chestnuts dwarfed to the size of bushes, yet bearing mammoth nuts, and of such precocity of habit as sometimes to begin bearing when only six months from the seed.

To be sure other chestnut strains were blended with the Japanese before these anomalous results were produced; but it is certain that the oriental parents had a strong influence in determining some at least of the most interesting peculiarities of the new hybrid races.

Very Mixed Ancestry

That the antecedents of the precocious chestnuts may be clearly revealed, let me say at the outset that the Japanese forms were hybridized with the three other species as soon as they were old enough to be mated, and that the hybrids in turn were crossed and recrossed until the strains

Yearling Chestnut Tree in Bearing

These precocious chestnuts are complex hybrids, combining the traits of European, American, and Japanese ancestors. Such chestnut bushes as this will perhaps take the place of the devastated chestnut forests of our eastern states.

had been blended of all the different kinds of chestnuts that could be obtained.

These included, in addition to the Japanese species just cited, representatives of the European chestnut in several of its varieties—one of which came from China—and of the native American chestnut of the familiar type; and also the little native species known as the Chinquapin.

It is interesting to record that the chinquapin, with its almost insignificant nut, crossed readily with the Japanese species, the mammoth nut of which would seem to place it in quite another class.

But, in point of fact, there is apparently a very close affinity between all the different chestnuts. All of them have varied and thus perpetuated forms that more or less bridge the gap between the typical representatives of the different species, and, so far as my observations go, all of them may readily be interbred. In a word, the chestnut furnishes most plastic material for the purposes of the plant developer. Just how I have utilized that material will appear as we proceed.

At the time when I received the chestnuts from Japan, there were already at hand trees of the European and American species of various sizes. So soon as the Japanese seedlings were of sufficient size, I grafted them on these European and American trees, in this way being able to stimulate

development, and to observe the progress of cions from several hundred seedlings on the same tree.

This, of course, is precisely the method I used with my plums and other orchard fruits. The advantages already detailed in connection with the orchard fruits were found to apply equally to the chestnut. The engrafted cions were led to fruit much earlier than they would have done on their own roots; there was saving of space; and it was easy to hybridize the many cions that were thus collected on a single tree.

Of course, I was carrying forward numerous experiments with the chestnut at the same time—crossing each species with every other species, so that in a single season there would be a large number of hybrid forms of different parentage. So when two of the hybrids were interbred, the strains of four different species or varieties were blended. Thus a hybrid of the second generation might combine the ancestral strains of the Japanese and European and American chestnuts and of the little chinquapin.

Moreover I had opportunity for wide selection among hybrids that combined these various strains in different ways. And for the next generation, I could combine different hybrids or inbreed a given strain or introduce the traits of a different variety as I might choose.

Branch of a Six Months Old Chestnut

The picture shows the way in which the chestnut burs form in relation to the catkins. Many of the hybrid chestnuts have the peculiar quality of putting forth blossoms at almost every season, so that flower buds and blossoms and mature fruit, may be found on the same branch.

In point of fact, all these methods were utilized, and in addition, of course, my usual method of rigorous selection was employed, so that I soon had a colony of chestnuts not only of the most complicated ancestry, but also a carefully selected colony in which none that did not show exceptional traits of one kind or another had been permitted to remain.

Precocious Traits

Of the many rather striking peculiarities of the new hybrids, doubtless the one that attracts most general attention is the habit of precocious bearing.

From the outset my hybrids were urged to early bearing, by the method of grafting and selection, as already noted; and of course I saved for further purposes of experiment only the individuals that were the most precocious. But, even so, I was not prepared to find my seedlings bearing large nuts in abundance in eighteen months from the time of planting the seed. Yet such extraordinary precocity as this was shown by many of the seedlings in the third and subsequent generations.

Moreover, if the grafts are taken from the seedlings and placed on older trees, they would produce, although not so abundantly, within six months after grafting. During the past ten years, seedlings have quite often produced nuts, like

annual plants, the first year of planting, while growing on their own roots, and when not over twelve to eighteen inches in height.

The value of such habits of early bearing, from the standpoint of the plant developer, will be obvious. Ordinarily one must expect, in dealing with nut-bearing trees, to wait for a long term of years between generations. In the case of the hickory, for example, after one has planted the nut, it cannot be expected that the seedlings will bear flowers and thus give opportunity for a second hybridizing for at least ten years, and no large crop of nuts may be produced till the tree is forty or fifty years old. So even two or three generations of the hickory compass a large part of a century.

But with my new hybrid chestnuts, generation may succeed generation at intervals of a single year, just as if we were dealing with an annual plant instead of a tree that may live for a century. And of course to this fact very largely I owe the rapid progress of my experiments in the development of new varieties of chestnuts.

Not only do the mixed hybrids show this extraordinary precocity, but some of them also develop the propensity to bear perpetually. On the same tree may be found at a given time flowers and ripe nuts. Flowers both staminate and pistillate ap

A Goodly Crop

The picture shows the tops of several yearling chestnut "bushes." It will be seen that these young plants are heavily laden with large burs. Within the burs, nuts of large size are maturing.

pear on the same tree from time to time, season after season, and in due course the flowers are replaced by growing nuts, so that there is a regular succession month after month.

This habit of perpetual bearing, manifested by a tree that ordinarily produces its flowers and in turn its nuts at fixed seasons, is perhaps scarcely less remarkable than the habit of early bearing. Doubtless the two are genetically associated.

Chestnut Seedlings

The care of the chestnut seedlings presents no important complications.

My general plan in selecting seedlings for further tests is the same employed in the selection of seedling fruit trees. Prominent buds, large leaves, thick, heavy twigs, almost invariably forecast large, fine nuts. There is, however, an exception to be noted in the case of the Japanese chestnut, which has smaller leaves. It is necessary to bear this in mind in dealing with seedlings that have a Japanese strain. It is needless to say that the capacity to select the right seedlings for preservation is highly important, as an element in saving time and expense in the practical development of improved varieties of chestnuts.

I have already referred to the saving of time that may be accomplished through grafting the chestnut seedlings instead of waiting for them to

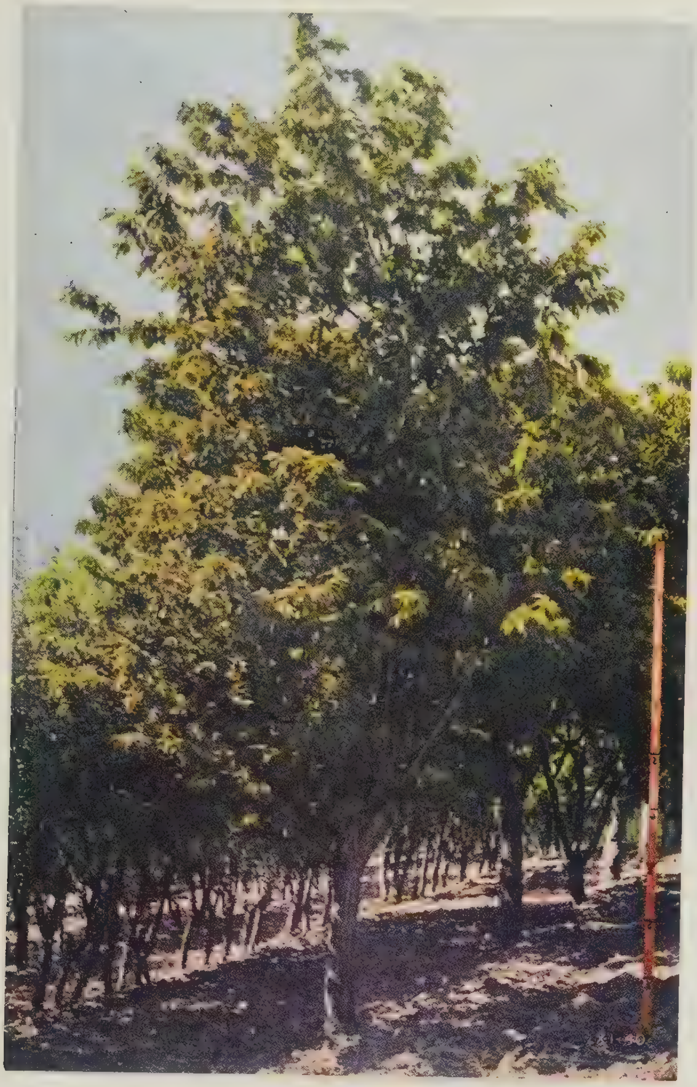
A "Low Head" Chestnut Hybrid

This hybrid chestnut is six years old, but has been headed in such a way that it forms a low bush. Compare with the tree of different type shown in the succeeding picture.

develop on their own roots. Unlike most other trees, the chestnut should not be grafted until just before the bark begins to slip in the spring. If grafted much earlier it is necessary to protect the grafts by tying a paper sack over them until they start growth to prevent evaporation; but in every case it is better to wait till shortly before the bark begins to slip. This is unlike the cherry, which must be grafted very early or success is extremely doubtful.

When grafting is performed after the bark begins to slip, it is necessary to tie down the bark against the graft with a string to keep it in place, otherwise it rolls away from the graft and union does not take place. If grafting is done at the right time and with reasonable care, it is usually successful.

In the main, very little attention has been paid to the chestnut by cultivators of nuts. Until very recently, such chestnuts as have appeared in the market have been gathered from wild trees, or, imported from Europe. Recently, however, the possibility of cultivating the chestnut has gained a good deal of attention and in a certain number of cases orchards have been started. I have introduced three different varieties of hybrid chestnuts, one of them known as the Hale, another as the Coe, and the third as the McFarland, and these



"High Head" Chestnut

This tree, like the one shown in the preceding picture, is six years old. Like the other, it is a complex hybrid, but it has been allowed to take on an upright growth, similar to that of the common American chestnut. The complex chestnut hybrids show the widest range of variation as to form and size and manner of growth.

have been grafted on ordinary chestnut stocks to form the basis of many chestnut orchards of the southern states.

In some cases the roots of the chinquapin have been used as the foundation for grafting, in regions where the ordinary chestnut does not occur. Chestnut orchards have also been started by planting the seed. Reasonable success attends this method, but of course it lacks the certainty of grafting. Now-a-days no one attempts to start an orchard except by grafting.

Unfortunately there has developed within very recent years a disease that attacks the chestnut tree and invariably destroys it. The disease at first appeared in the neighborhood of New York City about the year 1904, and it has spread in all directions each year reaching out a little farther, until in 1914 there were very few chestnut trees unscathed within fifty or sixty miles of the original center of contagion.

The cause of the disease is a fungus that is perpetuated by minute spores that are presumably carried through the air and that, when they find lodgment, develop in such a way as to destroy the cambium layer of the bark, presently causing the death of the tree. The small twigs of a single branch will often first show the influence of the fungus and the leaves may die and become brown

Chinquapins and Chestnuts

The chinquapin is a species of chestnut bearing very small nuts, which have, however, the typical chestnut form and quality. The picture, showing chinquapins at the top and chestnuts below, illustrates both the similarity in form and the contrast in size. The strains of the chinquapin have been combined with those of the other chestnuts in Mr. Burbank's complex hybrids.

and shriveled on one or two large limbs of the tree when no other part of it is affected. But in the ensuing season the disease is sure to spread, and the tree seldom survives beyond the third year.

As yet no way of combatting the pest has been suggested, except the heroic measure of cutting down trees immediately they are attacked, and burning every portion of their bark. In this way it is hoped to limit somewhat the spread of the disease but it is by no means sure that the method will be effective. There appears to be danger that the pest will spread until it has decimated the ranks of the chestnut throughout the eastern United States; and of course there is no certainty that it may not find its way to the Pacific Coast, although the lack of chestnut trees in the desert and plateau regions of the middle west may serve as a barrier.

The precise origin of the fungus that causes the disease was not known until the summer of 1913, when it was discovered by Mr. Frank N. Meyer, of the United States Department of Agriculture, that the fungus (which bears the name *Endothia parasitica*) is indigenous to China. The Oriental chestnut trees have become practically immune to it, however, and it does not destroy them, but merely blemishes their bark here and there with canker spots. No one knows just how the disease found

its way to the United States, but it presumably came on lumber brought from the Orient.

The appearance of this pest came as a very discouraging factor just at a time when interest in the chestnut as a commercial proposition was being thoroughly aroused. Government bulletins had called attention to the value of its nut and its possibility as a paying crop.

But, of course, all expectations were nullified in the regions where the ravages of the chestnut fungus are felt.

Fortunately, it appears that some of the hybrid races that bear the Oriental strain are immune to the disease. Observations as to this have been made very recently by Dr. Robert T. Morris, of New York. Reports show that hybrids between the Japanese chestnut and the American Chinquapin are peculiarly resistant. The chinquapin itself is at least partially immune to the disease, but of course this plant bears a nut that is too small to have commercial value. The hybrids, however, in some cases are said to retain the good qualities of the chestnut tree combined with the capacity to bear large nuts acquired from their Oriental ancestor.

It is obvious, then, that here is another case in which the introduction of new blood from the Orient may be of inestimable value. The loss of

A Typical Cluster

This typical cluster of hybrid chestnuts, in the formative stage, suggests the prolific bearing of the tree. What the hybrids lack in size, they appear to make up in productivity.

our native chestnuts is indeed a calamity, but it is a calamity that is not irreparable. We may have full assurance that new chestnut groves will spring up in the wake of the pest.

It is obvious that the quick growing chestnut offers great advantages for such reforestration. The probability that these will prove immune to the pest gives them added attractiveness. If, however, the existing varieties should prove not to be immune, it will be necessary to develop resistant varieties. For it is obvious that the cultivation of the chestnut will not be abandoned merely because it has met with an unexpected setback.

It has already been pointed out that the chestnut has exceptional food value on account of its high percentage of starchy matter. It therefore occupies a place in the dietary that is not held by any other nut. So there is an exceptional incentive to reintroduce the trees in devastated regions.

The Chestnut Orchard

Possibly the coming of the chestnut plague, even though it has resulted directly in the destruction of the entire chestnut groves throughout wide regions, may be a blessing in disguise, as it may make it necessary to bring the chestnut under cultivation in order to preserve the nut at all, whereas in the past it has grown so abundantly in the wild that little attention has been paid to it.

A Well Protected Fruit

Most of the hybrid chestnuts have a spiny covering that affords ample protection against the attacks of birds or squirrels. In this regard, the specimen here shown resembles the typical chestnuts of our eastern forests. There are other specimens, however, that tend to give up their spiny covering, and Mr. Burbank is using these in further experiments.

Accounts of the destruction of the trees have doubtless brought the chestnut to the attention of many people who hitherto have never given it a thought. The value of the chestnut as an ornamental tree and its possibilities as a nut producer will perhaps be more fully appreciated than they otherwise would be on the familiar principle that blessings brighten as they take their flight. And it may chance that the tree will be placed under cultivation so generally as to be more abundant twenty-five or thirty years from now in the devastated regions than it would have been if the chestnut blight had not appeared.

In any event it seems now at least as desirable as ever before to urge the value of this tree both for ornamental purposes and as a producer of commercial nuts, and the rules for the development of chestnut orchards that have been given by the Department of Agriculture may be reviewed to advantage.

Even if people living in the infected district are slow to take up the cultivation of the chestnut, the orchardists of other regions may advantageously do so. For I repeat that it is not supposable that the coming of a fungoid pest will be permitted to exterminate one of our most valuable native trees.

In developing a commercial chestnut orchard it is obviously desirable to graft with the improved

Chestnuts in the Burr

In this specimen, as will be seen, the spiny covering is relatively reduced, as compared with the bulk of the nuts within the bur. Contrast this specimen, with regard to its spiny covering, with the specimens shown in the succeeding pictures.

varieties. Quite aside from the matter of producing trees that are immune to the fungus pest, the orchard may be made far more productive if grafted with foreign stock than if the native species were used. And of course my new hybrid varieties offer attractions that excel those of any other variety of chestnut.

Some of my seedlings, for example, produce nuts two inches in diameter, each weighing an ounce or more; and these are borne in clusters of from six to nine nuts to the burr. It is notable, however, that the excessively large nuts are usually lacking in flavor; although the reasonably large ones are of the best quality.

These hybrid varieties graft readily on the native stock. They may be counted on to bear abundantly in their second season. It may be well, however, to pick off the burs as soon as formed during the first year or two, in order that the energies of the tree may be given over to the production of branches.

Even where the blight has destroyed the chestnut, the sprouts that spring up everywhere about the stumps of the trees may be grafted and trees of more satisfactory shape than the old ones and far more productive may thus be developed in the course of a very few years.

Where the chestnut orchard is developed from

the seed or by transplanting seedlings, it is recommended that it should be located on a well drained gravelly soil. The trees thrive well on rocky hillsides, and even on rather poor sand, but observation has shown that they are somewhat uncertain of growth on stiff clay soils in the east, although Italian chestnuts in California are said to thrive on heavy clays. In general, the experts consider it more important to have a thoroughly drained soil than soil of a particular character.

The authors of the Government Bulletin that has urged the merits of the chestnut as a commercial crop show that the chinquapin chestnuts are practically free from the blights that have hitherto menaced the American species.

It will be recalled that my new varieties were developed on the foundation of stocks imported from Japan. It will also be understood, as a matter of course, that my selections with this tree as with all other plants have been made always with an eye to the exclusion of any races that showed susceptibility to fungus pests of any kind.

As an illustration of the care with which these selections were made, in the development of the perfected varieties, I may note that in various instances only three or four seedlings were selected out of a company of ten thousand. I may add that orchards made by grafting cions of these im-

An Impregnable Fortress

Note the size and offensive or defensive quality of the spines that protect this chestnut bur. No bird or squirrel could hope to penetrate such an array of bayonets. Such a specimen, obviously, would not be among those chosen to carry forward an experiment in breeding the spines off the chestnut bur.

proved hybrid chestnuts on ordinary American stock have proved enormously productive.

It has been estimated that rocky and otherwise useless hillsides may be made productive, where practically nothing else could be grown that would be of special value.

Improvements to be Made

In continuing my experiments in developing the chestnut, I have endeavored to effect wider hybridizations. In particular I wish to cross the hybrid chestnut with the evergreen golden chestnut (*Castanopsis chrysophylls*) of California, but the wild trees of this species are so distant from my grounds that I have not found it feasible to gather their pollen, and the ones I have under cultivation, although fifteen years of age, have not yet blossomed.

This golden chestnut is a very remarkable species. On the heights of the Sierra Nevada mountains it grows as a shrub only four or five feet tall, much branched. These shrubs produce nuts quite abundantly. Along the coast the same tree grows to a height of 150 feet, with an immense trunk. One can scarcely believe that the little bush and the gigantic tree are of the same species.

In point of fact there is a considerable difference in the constitution of the two varieties, the giant from along the coast being rather tender,

Exposed Treasures

Fortunately the bur of the chestnut opens spontaneously, when the nuts are ripe. Now they invite the squirrels to which they were hitherto altogether inaccessible, and the little rodents are certain to drop a specimen here or there by accident or to bury it where it is forgotten, thus inadvertently helping the parent tree to scatter its progeny into new territories.

while the bush-like mountain form is very hardy.

Being an unusually ornamental evergreen the mountain variety should be extensively planted in cold climates.

I am inclined to believe that the golden evergreen chestnut and the chestnut oak could be combined by crossing. If so, remarkable trees could be produced.

As yet, however, I have not been able to attempt this hybridization, nor, indeed, have I as yet hybridized the golden chestnut with the ordinary chestnut, for the reason above stated.

I have made tentative efforts, however, to cross my early bearing hybrid chestnuts with the California tanbark or chestnut oak, *Quercus densiflorus.*

Notwithstanding the wide difference between the species, numerous nuts were produced and it seems probable that these were hybrids. As to this, however, I cannot be certain until the seedlings have come to maturity.

The object of such wider hybridizing is, in particular, merely to test the possibilities of crossing a plant that shows a high degree of inherent flexibility. But it is also desirable for practical reasons to accentuate the variability and to carry forward further series of experiments in selective breeding.

Chestnut Bur of Another Type

There are usually only two or three chestnuts in a bur, but sometimes, as we have seen, the number may be increased to four or five. The hybrid chestnuts have been selected for prolific bearing, and their nuts are not only of very large size but are usually borne in large clusters. This picture shows the typical arrangement when there are three nuts in a bur. Compare with the preceding picture, with its large cluster.

There is a great difference among the different chestnuts as to the amount of their sugar content. In some species the starch is so little transformed that the nuts are scarcely edible unless cooked. In others there is an abundant sugar content the nuts being sweet and palatable. Of course I have had this matter in mind in developing my hybrid varieties. But there is still opportunity for improvement.

It is also desirable to reduce the amount of tannin contained in some of the chinquapin varieties.

Some of the chinquapin varieties also have the habit of holding the leaves during the winter, giving the trees a very untidy appearance. Seedlings that show this tendency should be avoided in making selection.

Points in Selection

Of course it is elementary to say that the nuts should be selected for dark, rich, glossy brown color, for tenderness of flesh, and for productiveness. Of my three introduced varieties, all were early and abundant bearers, but one was particularly notable for its earliness, and another for its combination of good qualities.

Doubtless the feature that is next in line of improvement in the development of the chestnut is the bur itself, which should be made spineless.

Bur and Catkin

It always seems matter for surprise that the round burs of the chestnut should grow in catkins that seemed destined to produce fruit-clusters of a quite different type. Here is a picture that emphasizes the contrast, as it shows a well developed bur in connection with the remains of the catkin. As the staminate and pistillate flowers of the chestnut are borne in different clusters, cross pollenization is very readily effected.

In the wild state, the chestnut needs a spiny bur to protect it from squirrels and birds. It has developed this protective covering through natural selection, just as the walnut has developed its thick coat filled with bitter and astringent juices. But the cultivated chestnut does not require the protective spines, and it will be obviously advantageous from the standpoint of the cultivator to have these removed.

I have for some years been working on the hybrid chestnuts with this in mind. I now have one variety that is relatively spineless, its burs not having more than one spicule where the ordinary chestnut bur has ten. There is every reason to expect that in a few generations more I shall develop a chestnut that has a bur as smooth as that of the walnut. The partially spineless variety that I have developed has nuts that are not as large or as good in quality as could be desired. But for the moment I am selecting it solely with reference to the removal of spines; being confident that once this is attained there will be no difficulty in breeding the good qualities of the hybrid nut into the combination.

The new partially spineless variety has been developed merely by selection from a hybrid seedling that produced nuts showing a tendency to have fewer spines than ordinarily. Of course the

tendency to vary in this regard was accentuated by hybridization just as were other tendencies. Or, stated otherwise and a little more technically, the hybridization has made possible the segregation of hereditary characteristics, bringing to the surface factors for spinelessness that no doubt have been transmitted as recessive traits for a very large number of generations.

Doubtless there was a time when the chestnut did not have a spiny bur.

So my spineless variety, when perfected, will represent a remote reversion, or the bringing to the surface of a tendency that has long been submerged.

No doubt difficulties will be involved in perfecting the race of chestnuts with smooth burs similar to those that attended the development of the thornless blackberry and the spineless cactus. But there is reason to expect that the same measure of success will be attained with the chestnut that was attained with the other spine bearers.

A nut that combines all the good qualities of my hybrid early bearing chestnuts and in addition is born in a spineless bur would have a combination of qualities that should appeal to the orchardist, and doubtless will do so when the idea that nuts may form valuable commercial crops gains wider vogue.

A Hickory Tree

The hickories are native American trees celebrated for the quality of their wood as well as for their nuts. In some parts of New England the hickory is colloquially known as the "white walnut."

The Hickory Nut—And Other Nuts

Improvements Which Have Been Wrought And Some Suggestions

THERE is perhaps no other wild plant producing a really delicious food product that has been so totally neglected by the cultivator as the shagbark or shellbark hickory tree.

The better varieties of hickory-nuts always find a ready sale in the market, and are highly prized by the housekeeper. But such nuts as find their way to the market are almost without exception the product of wild trees, gathered usually by some wandering boy, and often regarded as the property of whoever can secure them, regardless of the ownership of the land on which the tree grows.

Even the new interest in nuts as food products and as orchard crops that has been developed in our own generation, has not as yet included the hickory, or at least has not sufficed to bring the hickory tree from the woods and give it a place within the territory of the orchardist.

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The reason for this, doubtless, is that the hickory is a tree of very slow growth, and that it is also exceedingly difficult to propagate by budding or grafting, or any other process except from the seed.

The prospect of improving the product of a tree that does not bear until it is ten or fifteen years old, and that resists all efforts to force it to early bearing, is not alluring, considering the short span of human life. Yet we can scarcely doubt that the hickory nut will presently be brought within the ken of the plant experimenter, and that there will ultimately be developed nuts of very choice varieties, comparable in size, probably, to the English walnut, and having a quality that will place them at least on a par with any other nut now grown in the temperate zones.

Even in the wild state, the best of shellbark hickories bear nuts of unchallenged quality. It is a matter of course that these nuts can be improved by cultivation and selective breeding.

Material for such selective breeding is furnished abundantly by the wide variation of hickories in the wild state. I had observed this variation in my boyhood days, just as I had noted the variation in the chestnuts. The shagbark hickory, doubtless the best of the tribe, was quite abundant along the banks of the Nashua River near my

home, and I early learned to distinguish the great difference in the products of the trees, all of which, of course, were natural seedlings.

Among hundreds of trees there would be scarcely two that bore nuts of precisely the same appearance and quality.

Some of these hickory nuts were long and slender, with prominent ridges; some were short and compact and smooth in contour; some were very flat and others were nearly globular. The shell varied correspondingly in thickness, and the meat varied greatly in whiteness and in flavor.

As a boy I knew very well which trees to seek in the fall in order to secure nuts that were plump and thin-shelled, with sweet and delicious meats. It was only after the crop of these trees had been gathered that inferior ones gained attention.

I knew very well, also, that different trees varied greatly in productiveness, some bearing nuts so abundantly each year that the ground was literally covered when the nuts fell. Others produced nuts very sparingly.

The trees that thus varied as to their fruit, varied also in form, in size, and in rapidity of growth. In a word, the wild hickories represented numerous varieties that a boy could differentiate, whether or not a botanist might choose to classify them as members of the same species.

All these varied members of the shagbark tribe bore nuts that had an unmistakable individuality of flavor that distinguished them from any other nuts. Much as they varied in size and degrees of excellence, all of them were hickory nuts, and could be mistaken for nothing else. There were, however, other hickory trees growing in equal abundance on my father's place, though they differed essentially in appearance from the shagbark nuts, that produced nuts of a far less interesting character.

Hickories of this kind were locally called pig-nuts. They are classified by the botanist as *Hicoria glabra.*

The trees of this species are more upright and symmetrical, and of much more rapid growth than the shagbark. The nut has a thin husk-like shell, but the meat is difficult to remove, and is so ill-flavored that it is little prized by any one. Indeed, the nuts are usually not gathered at all if shagbark hickories of any quality can be obtained.

Nevertheless, there was great diversity among the pig-nuts no less than among the hickories of the better species. So with these also there is doubtless opportunity for improvement through selective breeding, although up to the present time no comprehensive experiments in this direction have been made.

Hickory Nuts

There is marked variation in the size, form, and quality of the nuts of different hickory trees, even when growing in the same neighborhood. Thus their is good opportunity for selective breeding, but unfortunately the hickory is of such slow growth that few experimenters have the courage to undertake its development. The hickory does not ordinarily bear nuts until it is ten or twelve years old.

I have now little doubt that some of the variant hickories that I knew as a boy were hybrids.

The two species of hickory are closely related, and I have reason to believe hybridize not infrequently in the wild state. I have received specimens of hickory nuts from different parts of the United States that I feel certain were natural hybrids. And I entertain no doubt that such hybridization occurs not infrequently.

It is probable that when the attempt is systematically made to develop the hickory nut the method of hybridizing the two species will be employed to give still wider variation and to facilitate a wider selection.

Some Enormous Hickories

There is a variety of the hickory nut that grows in the valleys of the Mississippi and the Ohio that is of relatively enormous size. The shell of this variety, however, is thick, and the meat is not generally as fine in flavor as that of the eastern shellbark hickory. But the size of this wild variety gives assurance that under cultivation and selection the nut may be made to take on proportions that will be very attractive. Doubtless the comparatively small size of the wild hickory nut has led to its neglect, although we must recall that the walnut and the butternut have also been neglected, notwithstanding their much larger size.

The chief reason why these nuts have been overlooked, doubtless, is that the idea of making nuts a cultivated crop, comparable to orchard fruits, has only recently been conceived in America —or at all events has only recently been given general recognition.

It is not improbable that it may be found feasible to hybridize the hickory with the black walnut or the butternut. These trees, to be sure, do not belong to the same genus, but they are not very distantly related, and we have seen that generic bounds do not necessarily constitute impassable barriers.

Could hybridization be effected between the hickory and either the walnut or the butternut, the product should be a nut of very great value.

It would be necessary, of course, to breed selectively, doubtless for a number of generations, to secure size and quality, and in particular to develop a race of thin-shelled nuts. But that all this may be accomplished cannot greatly be in doubt. In any event, the experiment is well worth making.

There is reason to expect that the next three or four generations will see somewhat the same rapid progress in the art of developing the nut-bearing trees that has been witnessed in the past three or four in the development of orchard fruits.

And certainly the hickory nut, walnut and butternut constitute better native material than the wild plums, for example, with the aid of which some of the finest varieties of cultivated plums have been developed within the most recent years.

And, indeed, it must not be forgotten that the work of developing our native nuts has already passed the experimental stage with regard to at least one species. This is the nearest relative of the hickory, a member indeed of the same genus, which is familiar as the pecan.

This nut grows only in the southern parts of the United States, being far less hardy than the other hickories. But what it lacks in hardiness it makes up in quality, and it is pretty generally regarded as the best nut that is grown in temperate climates, not even excepting the English walnut.

The relationship between the northern hickories and the pecan is attested by the fact that in the regions where the two tribes intermingle, they hybridize freely.

I have received specimens of the nuts that were undoubtedly hybrids between the shagbark hickory and the pecan, and these included two or three varieties that are among the finest nuts that I have ever seen.

The seedlings that grew from them included two trees that gave great promise. Unfortunately

A Butternut Tree

The butternut is an indigenous tree, closely related to the black walnut. As a timber tree, it is inferior to the walnut, but it bears a nut of very exceptional quality. It is to be hoped that someone will make the experiment of hybridizing the butternut and the walnut.

the gophers destroyed them both. So the experiments I had contemplated in connection with them were not carried out. But I am confident that great improvements in the pecan will result from hybridizing this nut with the shagbark hickory.

The Cultivation of the Pecan

Even in its existing varieties, however, the pecan nut has very attractive qualities; and it has the distinction of being the only native nut that has hitherto been placed under cultivation on an extensive scale and has attained commercial importance.

We have already referred to the economic importance of this nut in an earlier chapter, and mention was there made of the fact that all the pecans now under cultivation are directly derived from a few wild varieties that have been propagated by budding and grafting. It is only in recent years that a method of grafting this nut successfully has been developed, and as yet little or nothing has been done toward improving the wild varieties.

The fact that the nut in its wild state has such attractive qualities gives full assurance that under cultivation and development it will prove of even greater value.

In selecting the best wild varieties for cultivation, attention has been paid to the matter of early

bearing, and in particular to persistent bearing. So the orchards that have recently been started are stocked with trees that may be expected to bear crops of nuts in about seven or eight years, and that may be depended on to produce a crop each year with reasonable certainty. But as to both time of bearing and regularity and abundance of production, there is still opportunity for much improvement.

Doubtless improved varieties may be secured through mere selection by raising seedlings from the nuts grown on trees that were especially good bearers. But it is probable, also, that the full possibility of the pecan will not be realized until extensive series of hybridizing experiments have been carried out.

I have spoken of the natural hybrids between the pecan and the shagbark hickory. Hitherto, no extensive experiments in hybridizing these species have been carried out, although it is possible that some of the wild varieties of pecans that have been brought into the orchard were natural hybrids.

It is to be hoped that experiments along this line will be taken up in the near future, but, of course, many years will be required before notable results can be attained.

It is desirable, also, to attempt hybridizing the pecan with the butternut and walnut, and with the

A Pecan Tree

The pecan is closely related to the hickory, but is a much less hardy tree, being confined to our southern states. It sometimes hybridizes with the hickory in the wild state, and it is possible that new and hardy varieties of nuts might be produced by selection among the progeny of such a cross. The pecan is rapidly assuming importance as a commercial nut.

English walnut and the Japanese walnut. If hybridization could be effected, it may be expected that trees of rapid growth, similar to my hybrid walnuts, will be produced. Not unlikely some varieties that tend to produce nuts at a very early age, like my hybrid chestnuts, may also appear as the result of such combinations. And in any event it may confidently be expected that new varieties will give opportunity for wide selection, and for relatively rapid improvement in the qualities of the nuts themselves.

We have learned that the pre-eminent qualities of our various cultivated fruits have largely been given them by hybridization.

The contrast between the tiny beech plum, for example, and its gigantic descendant a few generations removed, offers an object lesson in the possibilities of fruit development by hybridizing and selection. And, for that matter, each and every one of our improved varieties of orchard fruits teaches the same lesson, even though the wild progenitor is not at hand for comparison.

So there is every reason to expect that the wild pecan will similarly respond to the efforts of the plant developer, and that its descendants, a few generations removed, will take on qualities that even the most sanguine experimenter of to-day would scarcely dare to predict.

One improvement that might probably be secured without great difficulty is the introduction of the quality of hardiness, so that the pecan might be cultivated farther to the north. At present the pecan does not produce profitably as a rule, even in the coast counties of California, as the nights are too cool, thus making the season too short for the pecan to ripen its fruit. About Vacaville they thrive much better, and the Sacramento and San Joaquin Valleys, where the nights are very warm, there is as good prospect of growing the pecan profitably as anywhere else in the world. But in the main the cultivation of this nut has hitherto been restricted to the region of the Gulf of Mexico. It is obviously desirable that so valuable a nut should be adapted to growth in wider territories.

The fact that the pecan will hybridize with the hardy hickory obviously points the way to the method through which this end may be attained.

The peculiarity of the hickory and pecan that is associated with their long life and slow growth, is the fact that during their first year the seedlings make perhaps 99 per cent. of their growth under ground. They produce enormous roots before they make any appreciable growth above ground.

It is nothing unusual to find pecan seedlings an inch high with roots from four to six feet in length, and an inch in diameter at the widest part.

The Hazelnut

The hazelnut grows wild in many regions of our eastern and central states, but it is almost never seen under cultivation. There are several varieties, and they would probably repay experiments in selective breeding. There is no reason why the hazelnut should not have commercial value if properly cultivated.

Such a root system prepares the tree for the strong growth that characterizes it later; but a seedling that makes only a few inches of growth in the first season is a rather discouraging plant from the standpoint of the cultivator. Doubtless the pecan may be induced to change its habit in this regard by hybridizing. The example of the hybrid walnuts may be cited as showing that a tree that is ordinarily slow of growth may be made to take on the habit of very rapid growth without relinquishing any of its other characteristics of hardiness and the production of valuable timber.

The case of the Royal walnut shows also that the tree that thus becomes a rapid grower may also have the habit of enormous productivity.

If the pecan could similarly be stimulated to increased rapidity of growth, and to a proportionate capacity for nut bearing, this tree would be a fortune-maker for the orchardist. And there is no obvious reason why the pecan should not have the same possibilities of development that have been demonstrated to be part of the endowment of its not very distant relative, the walnut.

Filberts and Hazelnuts

There is yet another native American nut as hardy and as widespread as the hickory, that has been even more persistently neglected. This is the familiar hazelnut.

There are two familiar types of hazelnut that often grow in the same region, and that resemble each other so closely that the boys who gather the nuts commonly do not discriminate between them. One of these grows in husks with a long beak, while the other has an incurved husk that in some cases does not fully cover the nuts. There are sundry varieties of the two species that may sometimes be found growing in the same patch.

The fact of such variation in the wild species is of course important from the standpoint of the would-be plant developer. We have learned from frequent repetition that where there is variation there is opportunity for selection and improvement.

The hazelnut has a European relative that is as familiar in America as the filbert. This is merely a larger hazelnut, the qualities of the two nuts both as to form and flavor being such as to leave no question of their relationship. But for some reason the European nut appears not to thrive in this country. At all events it has never been cultivated here on a commercial scale.

But for that matter the hazelnut has never been cultivated on a scale commercial or otherwise, unless in the most exceptional instances when it has been brought into the garden by some one rather as a curiosity than for any commercial pur-

The Wild Nutmeg

The nutmegs belong to the genus Myristica. They are mostly tropical plants and must be cultivated under glass if grown in northern regions. Mr. Burbank has experimented with the nutmegs, as well as with many other tropical nuts.

pose. Yet the nut is a really valuable one, and certainly it is one that would repay cultivation and development.

Attempts have been made to grow the European filbert in Sonoma County, California, both from seed and from division, but in all cases these attempts have failed. The purple-leaved hazelnut grows and thrives here in California as it does almost everywhere else in the United States. The species known as *Corylus rostrata* grows wild rather abundantly in certain sections, but so far as I have observed, it is a shy bearer.

There is no obvious reason why the European filbert should not be cultivated in this country if a study is made of its needs as to soil and climate. Also, there is no seeming reason why it should not be hybridized with the American hazelnut. The result of such hybridizing, if we may draw inferences from analogy, would be the production of a race of hazel-filberts of greatly increased size, and of improved quality.

There is a so-called filbert, or Chilean hazelnut, that grows in South America. This plant bears a nut similar to the filbert, but much larger in size and of far better quality. It is difficult, however, to get a start in the cultivation of this plant, as its seeds when brought to this country ordinarily do not germinate. I have at last succeeded, however,

in producing several young trees. The nut is four times as large as the hazel nut. This is a beautiful tree, and should prove of great value. In its own country the plant is very highly prized, selling for a large sum when only a few inches high.

The European filbert grows readily from the seed, but does not by any means come true. Indeed, it proves exceedingly variable. But this, of course, from the standpoint of the plant developer could not be regarded as a fault. If through selective breeding a variety could be produced that would bear regularly and abundantly, and in particular if the size of the nuts was increased, this would be one of the most important of all nuts. As yet, however, a variety that is adapted to growth in this country has not been produced.

So there is abundant opportunity for work on the part of the plant experimenter.

With the American hazel and the European filbert for material—whether or not further aid may be expected from the Chilean species—there is opportunity to produce a nut that will amply repay almost any experimenter for the time and labor that may be spent upon it.

Some Foreign Possibilities

A nut that has come to be fairly well known in the market in recent years, but which has hitherto scarcely been grown in this country, is the

A Variety of Tropical Nuts

Mr. Burbank has often said that he would like to have a laboratory in the tropics, where he could experiment with the vast number of plants that have never been brought under cultivation. In default of that, he experiments with great numbers of seeds sent him from the tropics. Here are a few specimens among the many, these being tropical nuts with which he chances to be experimenting at the present time. Just what will come of these experiments, it would be futile to predict.

Pistachio. The tree on which this nut grows is a member of the sumac family. The nuts are small, but on the best trees are produced in profusion.

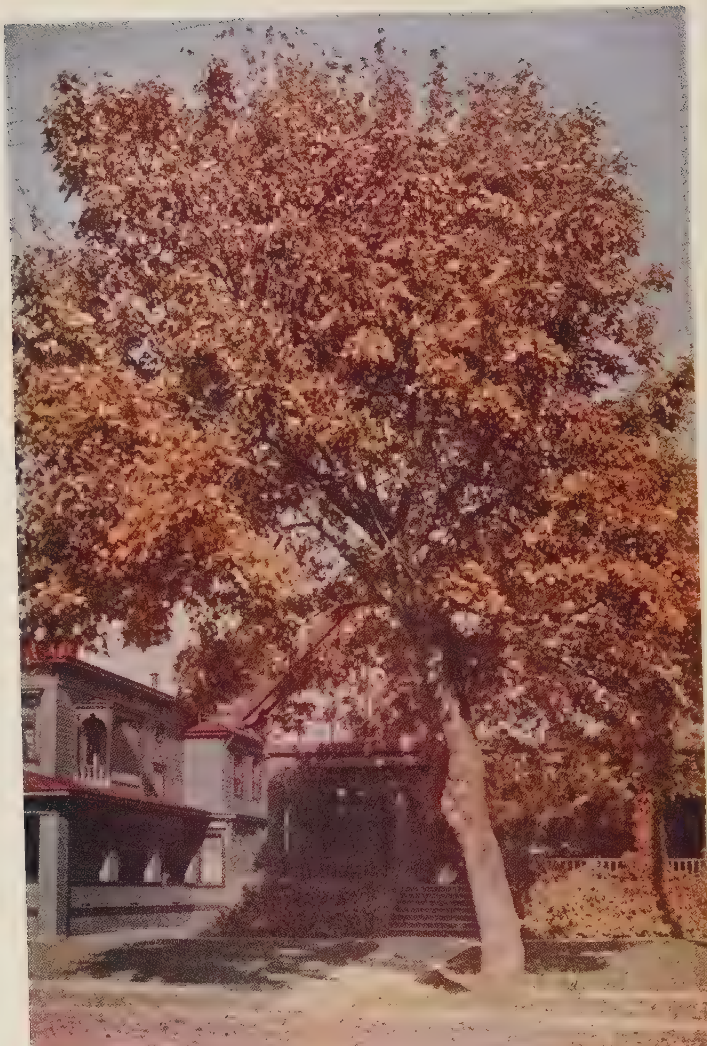
In recent years the Department of Agriculture of the United States Government has imported a great number of plants and seeds of the pistachio, which are now being grown experimentally, and which, it is hoped, will form the basis of an extensive culture of this nut. The experiment has not as yet progressed far enough to make prediction possible as to the results. My own experience with the nut is limited to the growing of a single plant about twenty-five years ago, which, after I had cultivated it for a dozen years was found not to be a fruiting variety, and so was destroyed.

An Australian tree-shrub or small tree, called the *Macadamia ternifolia,* has been introduced in California in recent years, and is regarded as a valuable acquisition. The tree is ornamental, and it bears a fruit that is regarded as of value. At the center of the fruit is a round, delicious nut, much larger than the ordinary filbert, indeed, sometimes almost equaling a small English walnut, that is fully equal in flavor to the best filbert or almond.

The Macadamia has proved hardy in this vicinity, but requires a well-drained soil. A wet winter is very destructive to the trees, unless they are on dry, well-drained land.

There are several species of Macadamia, the one that I have raised most extensively being known as *Macadamia ternifolia*. This is a handsome evergreen, the leaves of which resemble those of the magnolia, but are thinner and rougher. The nuts are often an inch in diameter, with rather thin shells, and large, round, delicious meats. Further tests will be necessary before the climatic limitations of the Macadamia are fully established. But in regions where it can be grown, it must prove a nut of very great value.

—The prospect of improving the product of a tree that does not bear until it is ten or fifteen years old, is not alluring, considering the short span of the human life; yet we can scarcely doubt that even the hickory nut will presently be brought into the dominion of the plant experimenter.



A Maple Tree

Maples of various species are among the most attractive of our indigenous trees. They are ornamental in our parks and dooryards, some of them furnish timber of very high grade, and one of them furnishes a sap that is transformed into the most delectable of sugars. The California species here shown is chiefly prized for its ornamental qualities.

On Growing Trees for Lumber

Ideas On Profitable Re-Forestration

A GOOD many years ago I had a talk with an official connected with the Department of Forestry, at Washington, in which I suggested that the problems of his department could best be met by the development of new types of forest trees.

The official regarded the suggestion as grotesque. In common with nearly everyone else at that time he looked upon the tree as a fixed product of nature, quite beyond the possibilities of any change that man could direct.

That was the time when Darwinism, although it had pretty fully established itself in the scientific world, was still on trial in the minds of the people in general. And even those who accepted the general truth of the Darwinian doctrine of evolution for the most part did not realize that evolution is a process that is going on about us

to-day along the same lines that have characterized it in the past.

To accept the doctrine of evolution at all required the overturning of the most fundamental ideas. After the conception had been grasped that in the past there had been eras of change and development, it was a long time before even the most imaginative scientist fully grasped the notion that our age also is a time of change and transition, and that the metamorphoses of plants and animals through which new forms have evolved in the past are being duplicated under our eyes in our own time.

And in particular, as regards so massive and seemingly stable a structure as the tree, was it peculiarly difficult for botanists to conceive of flexibility and propensity to change, or to evolve, in the present time.

It is true that no very keen eye was required to observe that trees differ among themselves within the same species, but it is also true that these divergencies always fall within certain limits and that on the whole they may be regarded as insignificant when weighed in the balance against numberless characteristics in regard to which the trees of a species seem practically identical.

Take, for example, all the individuals that one could observe of, let us say, the common shagbark

Two Cypresses

Here the Australian cypress is shown growing side by side with an unidentified variety. Note the very striking contrast in the foliage of the two species; but note also how the two show relationship in their tendency to towering, slender growth. The central stalk of each tree is as straight as the traditional arrow.

hickory, the variations of which were referred to in the preceding chapter. Attention was called to the fact that the hickories that I used to observe as a boy in the neighborhood of my New England home differed a good deal in size and form, and that the nuts that they bore were sometimes oval, sometimes rounded in form, sometimes rough, sometimes smooth, sometimes thick, and sometimes thin of shell, and equally diversified as to the quality of their meat. But of course I should be foremost to admit that all these diversities were in the aggregate of minor significance in comparison with the characteristics that even the most divergent of the hickories had in common each with all the rest. All of them were trees that attained a fair size as trees go.

All have roots and trunks and branches of the same general form and aspect—as much alike, for example, as the bodies and arms and legs of human beings.

All of them had leaves that could at once be distinguished as being leaves of the hickory and of no other tree.

All had bark with the same characteristic whitish color and the same propensity to scale off in layers; and although the bark of some was much rougher than that of others, any fragment of bark of any hickory tree could readily enough be dis-

tinguished as characteristic of the species, and as not by any chance having grown on any other kind of tree.

Then, too, if the hickory tree were felled and cut into fire wood, the texture and fiber of the wood itself enabled anyone who glanced at it to pronounce it hickory as definitely and with as much certitude as if he had seen the tree while living and in full leaf. No other wood had quite the same whiteness, quite the same strength and elasticity of fiber.

The Indians had learned this in the old days, and had used the hickory of a preference always in making their bows.

We boys, in our barbaric age, followed the Indians 'example. We knew that a bow of hickory had shooting qualities that no other bow could hope to match.

All in all, then, the hickory, despite the trivialities of variation which are mentioned in the preceding chapter, stands apart when we come to scrutinize it comprehensively, as a tree differing from all others and obviously entitled to stand as a unified and differentiated species.

And what is true of the hickory is no less true of each and every species of tree in our forest. Each walnut and oak and beech and birch and pine and linden and locust has a thousand points

A Hybrid Evergreen

This is a cross between the cypress and the juniper. Mr. Burbank notes that our evergreen trees frequently hybridize in a state of nature. This is not strange, considering that the conifers send out their pollen in clouds to be scattered at random by the winds.

of unison with every other member of its own species, could we analyze its characteristics in detail, for every conspicuous point of divergence. If we consider minutiae of detail as to size and exact form of leaf and all the rest, no two individuals are identical. But if, on the other hand, we take the broad view, it is clear that each recognized species stands out in a place apart, grouped with all the other members of its own kind, and somewhat isolated from all other species.

Such being the obvious fact, it was perhaps not strange that the botanists and foresters of twenty-five years ago looked almost with suspicion on anyone who suggested that the different species of forest trees might be interbred and modified and used as material for building of new species that would better fulfill the conditions of re-forestration than any existing species.

Even botanists who thought that they fully grasped the idea of Darwinian evolution looked askance at such a suggestion.

It seemed to bid defiance to the laws of heredity, as they understood them.

It appeared almost like an affront to Nature herself to suggest that her handiwork might thus be modified and improved.

Materials For Selection

And it may well be questioned whether this

point of view would have been altered even to this day had it not been for a conspicuous and notable demonstration of the possibility of modifying existing species of trees.

The demonstration was made when I took pollen from the flower of a Persian walnut and transferred it to the pistils of the California black walnut.

Here were two species of trees so notably different in form and shape of leaf and fruit and color of wood that not even the most casual observer could confound them. They were not even natives of the same continent, and no botanist would claim that they were as closely related as are many species of forest trees that grow side by side in our woodlands and maintain unchallenged their specific identity.

Yet when these two trees were cross-pollenized they produced fertile nuts, and trees of a new order grew from these fertile seeds.

The barriers between these not very closely related species were broken down, and a new type of forest tree was produced that differed so markedly from either parent that no one could confound it with either, and that excelled both in the capacity for rapid growth so conspicuously as to seem to belong not merely to a different species but to an entirely different tribe of trees.

A Young Eucalyptus Tree

Several species of eucalyptus have been introduced into California from the southern hemisphere. This specimen shows the remarkable symmetry and gracefulness of the eucalyptus when grown by itself.

The reader has already learned details of the history of this Paradox walnut, and we shall have something more to say of it in connection with a further interpretation of the laws of heredity, in a subsequent chapter.

Here I refer to it only in connection with the demonstration it gave of the possibility that new types of forest trees might be developed by hybridization and selection, quite as had been claimed in the comment that aroused such skeptical and even sarcastic response from the professional forester.

But, as I said, after this demonstration had been made, it was no longer possible even for the hidebound conservatist to deny the possibility that forest trees, like other plants, are somewhat plastic materials in the hands of the plant developer.

And in course of time it came to be recognized —though even now the knowledge has scarcely been acted on—that the new idea given by observation of the Paradox walnut could be utilized for the practical purpose of supplying us timber trees that might be expected to re-stock our woodland in a fraction of the time that would be required for the growing of trees of unmodified wild species.

The row of Paradox walnut trees which at fifteen years of age were two feet in diameter and towered as beautiful and symmetrical trees to the height of sixty feet, standing just across the street

from their Persian parent, which, at thirty-two years of age was nine inches in diameter and perhaps forty feet high, afforded an object lesson that even the most skeptical could not ignore.

"If new trees are needed to make forests to supply the place of those that your thoughtless forbears have destroyed," the trees seem to say, "why not call upon me and my fellows?"

And to such a question there seems but one rational response. The Paradox hybrid and its fellows must be called upon to re-stock the ravaged timber lands of America. New hybrids must be produced by the union of varied species of pines, oaks, and elms, and other timber and ornamental trees, to give diversity to the landscape and to supply different types of wood for the uses of carpenter and cabinet-maker.

The Paradox walnut stood there—and still stands—as the working model for a new order of mechanism—a timber tree that shall be able to re-forestrate a treeless region in half a human generation with a growth ready for the axe and saw of the lumberman.

The Materials At Hand

In preparing this new material for the making of forest trees, it will be possible, no doubt, to bring trees from foreign lands, either for direct transplantation or as hybridizing agents.

A Row of Eucalyptus Trees

The eucalyptus is a tree of astonishingly rapid growth, notwithstanding which its wood is hard and durable. The tree has such vitality that it sends out new shoots that rapidly attain tree-like proportions, even when the trunk is cut close to the ground.

Thus, as we have seen, one of the parents of the Paradox walnut was a tree not indigenous to America. But we may recall also that another hybrid walnut, the Royal, which sprang from the union of two indigenous species, the black walnut of the Eastern United States and the black walnut of California, rivals the Paradox in its capacity for rapid and gigantic growth.

So it is obvious that we are by no means reduced to the necessity of making requisition on foreign lands for material with which to develop our new races of quick-growing forest trees.

But, on the other hand, the plant developer is always willing, like Moliere, to take his own where he finds it. So if foreign species can be found that will hybridize advantageously with our native species, they will of course be welcomed. The reader will recall that I have invoked the aid of numberless exotic fruit trees and vegetables and flower bearers in the course of my experiments in plant development. There is every reason to expect that equal advantage will result from the utilization of forest trees from, let us say, Siberia in one hemisphere and Australia in the other to blend with the strains of American species.

In some cases it will be possible to bring the foreign species and acclimate them without hybridization. This has been done with several species

of eucalyptus which have been brought to California from Australia and have proved a wonderful addition to the ranks of our ornamental and timber trees.

Everyone who visits California marvels at the eucalyptus, and those of us who watch it year after year marvel equally, because this tree has capacity for growth that seems little less than magical. No other trees, perhaps, ever seen in America, with the exception of the hybrid walnuts, have such capacity to add to their stature and girth year by year as has the eucalyptus.

Moreover the eucalyptus may be cut down for timber, its trunk severed only a few inches above the ground; and it will send forth shoots that dart into the air and transform themselves into new trunks, each seeming to strive to rival the old one. From the roots of the fallen giant spring a galaxy of new giants, and each new shoot assumes the proportions of a tree with almost unbelievable celerity.

Add that the wood of the eucalyptus, notwithstanding its rapid growth, is of the very hardest, and the remarkable character of this importation from the Southern Hemisphere will be more clearly realized.

Unfortunately the eucalyptus is sensitive to cold; otherwise it would at once offer a solution of

In Mariposa Grove of Big Trees

The picture shows a Sequoia, or big tree, in the midst of various pines. Note the distinctive color, as well as the characteristic form of the Sequoia.

the problem of re-forestration throughout the whole of the United States.

Perhaps the eucalyptus may be made more hardy by hybridizing and selection. If not, we must take to heart the lessons it gives—in common with the hybrid walnuts—as to the possibility that a tree may show almost abnormal capacity for rapid growth and at the same time may produce lumber of the hardest texture.

Hitherto it has generally been supposed that a tree of rapid growth would as a matter of course produce soft timber. The hybrid walnuts and the various eucalyptus trees serve to dispel that fallacy.

Native Materials

The one fault of the eucalyptus, its inability to stand extreme cold, is likely to be shared by other trees that are imported from the southern hemisphere or from sub-tropical regions of our own hemisphere.

Although, as just suggested, it may be possible to overcome this fault through selective breeding, a long series of experiments will doubtless be necessary before this can be accomplished. In the meantime we shall be obliged to place chief dependence, in all probability, upon our native stock of trees, hybridized perhaps with allied species of Europe and northern Asia.

Yellow Pine

There are said to be more species of conifers in California than in all the rest of the world; and the very best of these, from the standpoint of the lumber man is the yellow pine, here shown. Note the absolutely straight trunk, holding almost the same size to a great height. Observe also that this is a very large tree, although not of course competing with the Sequoia and the redwood.

But, even so, there is no dearth of material. America is richly stocked with forest trees. Moreover these represent, so the geological botanists assure us, a flora of very ancient origin which has shown its capacity to maintain itself through successive eras during which there have been tremendous climatic changes.

It follows that our native forest trees have in their heredity the reminiscence of many and widely varying environments. And by the same token they have capacity for variation, and therefore afford exceptional opportunity for diversified development.

It is not necessary here to analyze in great detail the qualities of the different groups of forest trees. A brief summary of the characteristics of a few of the more important groups will serve to suggest the abundance of native material, and to give at least an inkling as to what may be expected, in the light of what was revealed by the experiments with the walnuts, as to possibilities of development of the different tribes.

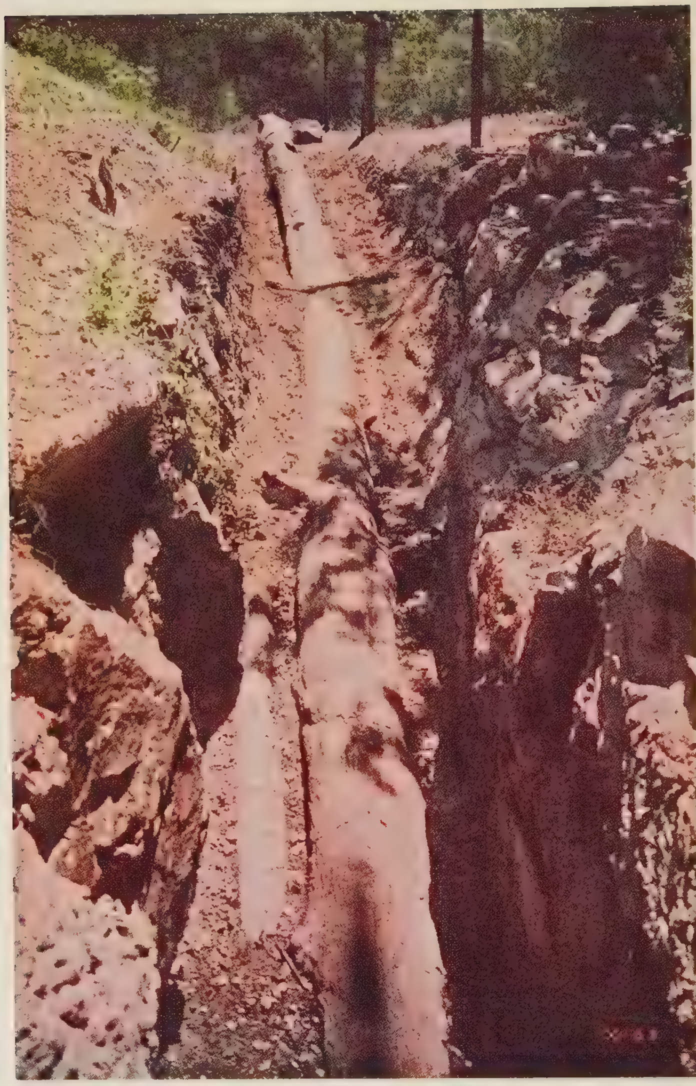
Of course the great family of cone-bearers stands in the foreground, represented by many species, and known as the timber trees that give us the pine lumber which has everywhere been the chief material for the carpenter, and an important foundation material for the cabinet-maker.

ON TIMBER TREES

We have but to recall the giant sequoia and redwood of California, the largest trees existing anywhere in the world, to be made aware of the possibilities of growth that are present in the racial strains of the family of cone-bearers. And even if these giants shall be regarded as representatives of an antique order that has outlived its era, there remain numerous pines and firs and hemlocks of magnificent proportions to test the skill of the plant developer for their betterment.

Moreover there is every probability that redwood and big tree may be crossed, and a variety produced that will be adapted to the new conditions, and which will outgrow all other trees.

Nothing could be easier than to cross-pollenize members of this tribe, inasmuch as the pollen is produced in the utmost profusion, and the pistillate flowers are exposed when mature in the nascent cones awaiting fructification. That cross-fertilization occurs among the wild trees through the agency of the wind is a matter of course. Doubtless there are hybrid species of pines and their allies, everywhere often unrecognized or classified as good species. Quite large forests mostly composed of hybrid cypresses are found in California, and the oaks are known to hybridize frequently; also the eucalyptus trees of various species.



A Petrified Pine

This tree is one of a large number in the petrified forest near Santa Rosa. The trees were overthrown by an earthquake and covered with volcanic ashes at a remote period of the past, and many of them became perfect petrefactions. A forest of large modern trees grows from the soil overlying the petrified forest.

If study were made of individual conifers in any forest region where different species are found, it would doubtless be possible to secure by mere selection new races that would admirably serve the purposes of the forester.

But of course still better results may be expected when hand-pollenizing is carried out intelligently, and the racial strains of different species of conifers are blended and tested to find just what are the best combinations.

It would be nothing strange if among the hybrids there should be found one or more varieties that will attempt to rival the Sequoia itself in giantism, and that will quite outrival it in rapidity of growth.

What the pines are as producers of white and relatively soft wood of straight grain and uniform texture, the members of the great family of oaks are as producers of wood of hard texture, irregularly grained and knotted, but capable to taking on a polish and serving almost every essential purpose of the cabinet maker.

The most famous of oaks, doubtless is the typical British species, but the American white oak is a close second. Perhaps these two might be hybridized. If the hybrid thus produced were by any chance to show the capacity for rapid growth that the hybrid walnuts have shown, while retain-

ing the hardness of texture of its parents, as the hybrid walnuts do, the tree thus produced would by itself go far toward solving the problem of re-forestration. The oaks quite frequently hybridize in a state of nature.

Granted a producer of soft white wood such as probably can be made by combining the white pine with some of its allies; a producer of hard cabinet wood such as a hybrid between the British oak and the American white oak would probably constitute; and the hybrid walnuts already in existence as producers of woods of the hardest and finest texture for cabinet purposes—granted further that the other new trees have the capacity for growth which the hybrid walnuts show—and a triumvirate of trees would be attained that could be depended on to go forth and gladden the devastated hillsides and valleys with trees that would jointly meet every need of carpenter and cabinet maker, adding incalculable billions to the wealth of our nation.

And of course we need not by any means confine attention to these few most typical trees. There are beeches and chestnuts that are near relatives of the oak, each of which serves its own particular purpose as the provider of wood having unique quality. The beech, for example, is prized by the chair maker for his furniture, and by the

A Young Giant Sequoia

This beautiful evergreen tree is a young Sequoia, about six years old, growing in Mr. Burbank's garden. Note the compact growth of branches from the very ground. Contrast this young tree with the old Sequoia shown in the next picture.

turner for the making of carpenter tools and such like instruments. The chestnut makes railroad ties that are thought to have no equal and telegraph poles of requisite strength and straightness.

Then there are other families that have their valued representatives. The hickories have already been referred to. The maples must not be overlooked, as they furnish highly prized white woods to the cabinet maker. The tulip tree supplies a light-colored wood used by cabinet maker and coach builder. The basswood or linden gives a wood of peculiar fiber that meets the needs of carvers and instrument makers. The willows and their allies; members of the birch family; the buttonwood tree or sycamore; and the locusts and their allies are other native trees that are of value as they stand and are well worth developing.

The plant experimenter who works with these different trees, being guided by their botanical affinities, but making careful tests even where he doubts the possibility of hybridization, will be almost certain to have his efforts rewarded by the production of some trees of new varieties that will not only duplicate the unexpected qualities of the hybrid walnuts, but will doubtless also reveal unpredicted traits that will give them added value.

Patience will be required in carrying out the work, for the tree is long-lived and experiments

in its development are quite different from those in the development of annual plants. Yet something of the probable results of an experiment can be judged even from observation of seedlings in their first year. And by hurrying the hybrid plants by the method of grafting, it will be possible greatly to shorten the generation.

Still it is not to be denied that the work of developing new races of trees is one that should preferably command the attention of the younger generation. In particular, it should be carried on under government supervision, as part of the great work of re-forestration, the necessity for which has only in recent years been clearly realized by those in authority or by the community in general.

Messages from the Past

The oft-cited hybrid walnuts supply us with tangible evidence of the possibility of developing new races of trees having much-to-be-desired qualities of rapid growth, through hybridization of the existing species.

Such evidence, as I have suggested, doubtless is more forceful and convincing than any amount of theoretical argument. But it may be of interest to support this evidence, and in so doing to reveal additional reasons for belief that the same principles will apply to other forest trees, by recalling briefly the story of the vicissitudes through which

The Largest Tree in the World

This giant Sequoia, growing in the Mariposa Grove, in the Yosemite National Park, is known as the "Grizzly Giant." It is 34 feet in diameter and 225 feet high. It is estimated to contain more than one million feet of lumber. The first limb is 100 feet from the ground, and 6 feet in diameter. Doubtless the tree originally had limbs all the way from the ground, but the lower ones have died in the course of the ages that mark the life of this extraordinary tree. Observe the man standing near the tree, by way of contrast.

the existing trees have passed and through which the diversified hereditary factors were implanted in their racial germ plasms.

A knowledge of this story we owe to the geological botanists. They have sought diligently in the rocks for fossil remains, and by joint effort, searching all around the world, have been able to reproduce a picture of the main story of the evolution of existing forms of vegetable life.

It is by recalling the story which they tell us, and thus alone, that we are enabled somewhat clearly to apprehend the possibilities of variation, and through variation of so-called new development—consisting essentially of the re-combination and intensification of old ancestral traits—that we have witnessed in the case of many tribes of plants in the course of our experiments.

A brief resume of this story of plant life in the past, with particular reference to our own flora, will serve in the present connection to explain why there is every warrant for believing that each and every one of our forest trees contains submerged in its heredity the potentialities of a development of which its exterior appearance gives but faint suggestion.

It appears that there is full warrant for the belief that the modern flora originated in the northern hemisphere, and probably in the region

of the north pole. During the so-called Mesozoic age, the conditions of the northern hemisphere were those that would nowadays be described as tropical or sub-tropical. There were palms growing in Europe, and such species as the sequoia, the plane trees, maples, and magnolias grew even at a relatively late period as far north as the seventieth degree of latitude. Remains of conifers have been found within nine degrees of the pole itself; remains of palms in Alaska coal measures, and of the sassafras along the western coast.

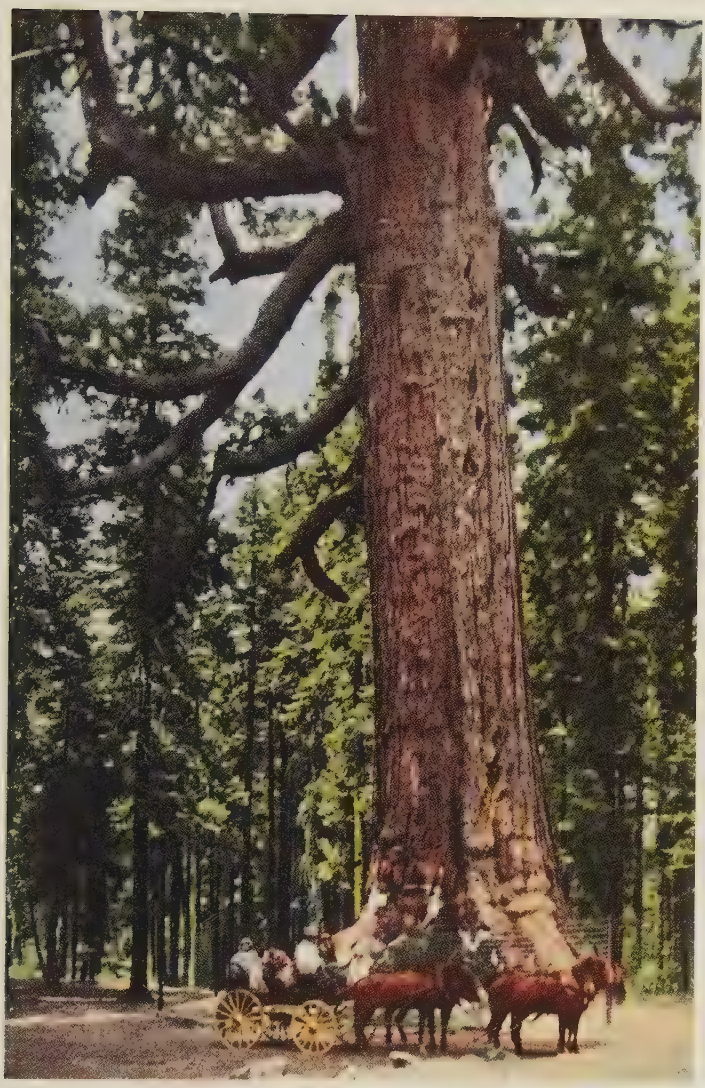
At this early period the flora of the entire northern hemisphere was, as regards its trees, essentially comparable to the existing flora of America to-day.

There were oaks and beeches scarcely distinguishable from existing species.

There were birches and planes and willows closely related to the living species known as *Salix cambida.*

There were laurels not unlike their modern representatives, the sassafras and cinnamon tree, and myrtles and ivies that are represented by existing descendants of allied forms.

And there were magnolias and tulip trees of which the existing tulip tree of the United States is an obviously direct and not very greatly modified descendant.



Another View of the "Grizzly Giant."

This wonderful tree leans more than 18 feet out of the perpendicular. The strain thus put upon the roots must be tremendous, but they show no sign of yielding. The tree shows signs of age, yet there seems no reason why it should not maintain its supremacy in the Mariposa Forest for a good many centuries to come. Almost the entire drama of the history of civilized man has been acted since this tree was a seedling.

All these trees grew far to the north, and luxuriated, as has been said, in a temperature that we of to-day would call sub-tropical, but which the inhabitants of that time, had there been a human population, would have described as arctic; for in that day it is probable that the north pole was tilted far toward the sun, and that the conditions that we now think of as tropical existed only in the region of the pole itself.

Then there came the slow progressive period of refrigeration. The tropical climate of the pole was succeeded by an age of ice, and the successive ice sheets slowly pressed southward, driving the plants no less than the animals before them along all parallels of longitude, until the flowers and faunas that intermingled in the arctic region were scattered along diverging paths to people the continents separated by the wide stretches of the Atlantic and the Pacific oceans.

It may seem strange to speak of plants fleeing before the ice sheet. But it must be understood that the plant is a migratory being, when considered as a race, notwithstanding the stationary habit of the individual. Plants put forth mobile seeds, and devise many strange ways of insuring their wide dissemination. They are always seeking new territories, and, granted proper conditions, always finding them.

Roots of a "Fallen Monarch"

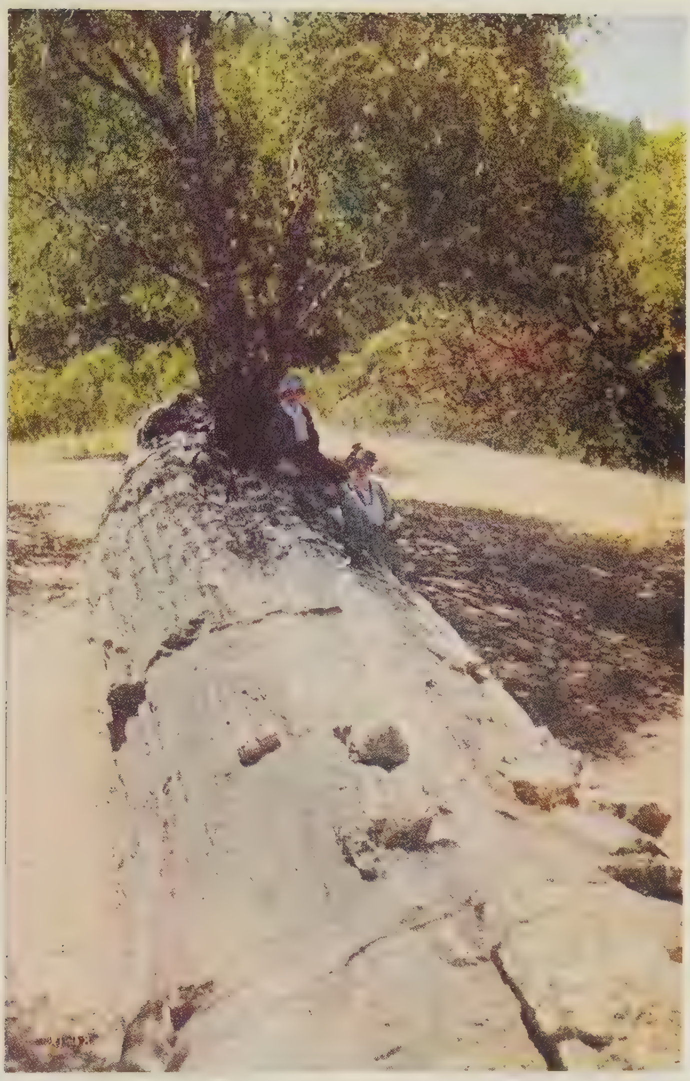
This is an overturned Sequoia in the Mariposa Grove. Note that the roots are extremely numerous, but that they extend symmetrically in all directions, there being no tap root. The failure to develop a tap root is perhaps due to the growth of the Sequoia in mountainous regions where the soil often has no great depth.

And it was only such plants as could migrate with relative celerity that were able to maintain existence and escape extermination by fleeing southward when the era of cold succeeded to the warm era in the arctic regions and when the arctic chill gradually spread southward and encompassed all the higher and middle latitudes of the northern hemisphere.

The plants that chanced to flee southward along the land surface that we now term Europe found their further flight checked when they reached the stretches of mountains extending east and west that we now term the Alps. Here thousands of species made a last stand and ultimately perished.

But the plants that were fortunate enough to choose the other avenues of escape, passing down across the land surface that we now term America and Asia, were not obstructed in their flight. Indeed, the long ranges of the Appalachians and Rockies and Sierras in particular served, as it were, to guide the line of march and aid the flight.

So the American species made their way to the region of the gulf, and some of them even to the southern continent. And when the ice sheet finally receded, they were able to make their way northward again, though never to their former habitat; whereas Europe was treeless until the plant life of Asia spread westward to re-people it.



A Petrified Redwood

This is one of the largest and most perfectly preserved specimens hitherto exhumed at the petrified forest, near Santa Rosa. It is a good sized specimen of the redwood (Sequoia sempervirens). Its entire substance is solid stone, but the appearance of the original texture of wood and bark is wonderfully preserved.

Such is the explanation that the paleo-botanist gives us of the fact that the indigeneous vegetation of America to-day is closely similar to that which stocked the sub-arctic regions of the entire northern hemisphere in the geological period known as the Mesozoic—a period that seems infinitely remote when measured in terms of human history, yet which in the scale of time as measured by the geologist is relatively recent.

Such trees as the sequoia, we are told, are survivors of that ancient regime that chanced to find hospitable shelter on the western slopes of the Sierras. Similarly the tulip tree of the east, with the blossoms that seem anomalous for a tree, should be regarded as the souvenir of a past age—a lone representative of vast tribes that once flourished in tropical luxuriance in regions that now give scant support to moss and lichen and stunted conifers.

All in all, we are told, the remaining vegetation of to-day, varied though it seems, is but a scant reminiscence of that of the period preceding the ice ages. Only a few species, relatively speaking, were able to make their migration rapidly enough to escape destruction. These included a certain number, like the sequoia and the tulip tree, that were able to reach coigns of vantage that permitted them to exist without changing essentially

from their sun-loving habit. But in the main the tribes that escaped destruction were those that developed a hardiness that enabled them to withstand extremes of temperature not far beyond the limits of the ice sheet. Others made their way northward again so soon as the ice sheet receded.

And as the climate of ensuing ages, after the successive periods of intense refrigeration, everywhere retained, throughout the central and eastern portions of America, curious reminiscences of both the tropical and the arctic, the plants that finally repopulated the devastated territories were those that had learned, through the strange vicissitudes of their ancestors, to thrive where the thermometer in summer might rise to the one hundred degree mark, and where in winter the mercury might freeze.

Such are the conditions under which pines and oaks and willows and beeches and black walnuts and allied trees exist to-day in the regions of northern America where they flourish.

They can withstand the glare of a tropical sun in summer because their ancestors reveled in a tropical climate. And they can withstand equally the arctic cold of winter because their ancestors of other ages were forced to subsist under arctic conditions.

The versatile tree that, thanks to the racial

Natural Grafts at the Petrified Forest

This tree is a live oak growing from the soil overlying the petrified forest. It is of peculiar interest because its branches form two natural arches through having grown together, constituting natural grafts. We not infrequently see the trunks of trees thus united, but such union of branches is very unusual.

recollection of these vicissitudes, can adapt itself to the inhospitable conditions of our modern climate are but dwarfed representatives of ancient races of giants. To preserve life at all it was necessary for them to conserve their energies; and gigantic growth is feasible only for plants that can send their roots into rich, well watered soils and can likewise draw sustenance perennially from the atmosphere, unhampered by long periods of dormancy when life itself is threatened.

But these dwarfed races carry in their germ plasm, submerged but not eliminated, factors for giant growth; factors for such development as would adapt them to life in the tropics; factors also for such development as would adapt them for life in the arctics.

Their hereditary factors, in a word, are as varied as have been their past environments. So, as I said, what each tree is exteriorly gives us but faint suggestion of what it might be were its unrealized hereditary possibilities to be made actualities.

So far as we know at present, the only way in which these unrealized possibilities may in any conspicuous measure be brought out is by hybridizing species that have so far diverged that they lie almost at the limits of affinity. By such union of hereditary factors that have long been dis-

united, racial traits that are reminiscent of the old days when the northern hemisphere enjoyed a tropical climate may be revived, and a tendency to repeat a gigantic growth that characterizes ancestors vastly remote will be revealed.

Such, I take it, is the explanation of the strange and otherwise inexplicable phenomena of gigantism manifested by my hybrid walnuts. And such is our warrant for believing that all other species of native trees have possibilities of development that are unrevealed in the exterior appearance of their present-day representative, and that can be revealed, so far as we know, only by hybridization.

—New hybrids must be produced by the union of varied species of pines, oaks and elms, and other shade and ornamental trees, to give diversity to the landscape and to supply different types of wood for use of carpenters and cabinet-makers.

The Production of a Quick-Growing Walnut

The Burbank Royal and Other Experiments

MY hybrid walnuts, already known to the reader as the Paradox and the Royal, were first publicly announced in my catalog called "New Creations in Fruits and Flowers", in June, 1893.

The hybrid walnuts themselves were then five or six years old and the Royal had borne fruit, so that a photograph of its large-sized nut could be given. The Paradox, on the other hand, although it had flowered for several seasons, had produced no fruit. It was supposed, therefore, that it would be impossible to reproduce this hybrid from seed.

In subsequent years, however, the Paradox proved its capacity to produce fertile fruit, although it was never a free bearer. And in my supplementary catalog of the year 1898, I was able to offer seeds of the Paradox for sale, and to make a statement as to the manner of seedlings that

might be expected to grow from these seeds. The statement, in view of the date when it was printed, has somewhat exceptional interest in the light of later developments, so I quote it here.

It was as follows:

"The six beautiful specimens of this hybrid growing on my home place have been objects of admiration to all who have seen them.

"Young trees could have been sold at almost any price, but, having no time to raise them, offer this season's crop of nuts which will be a great surprise in producing about one-third of a new type of the broad-leaved Persian walnuts, one-third of a new type of the California black walnut, and about one-third combined, as in the original tree."

The "original tree" in question was, of course, the hybrid called the Paradox, produced by crossing the California walnut and the Persian walnut. So the seedlings, the character of which is predicted in the paragraph just quoted, would of course represent second generation hybrids from this cross.

I make the quotation here, carefully specifying the date at which the original was printed, because there is a certain interest in knowing that tests made prior to this time with the seeds of the hybrid walnut had clearly revealed to me the fact

that "about one-third" of the second generation hybrids would revert toward one parent, while another third would revert toward the other parent, the remainder being intermediate in character, and in this corresponding to the first generation hybrid that was their parent.

This implies a fair understanding of the combination of characters of the two parent species in the first generation hybrid, and the segregation and recombination of these characters in the second generation hybrid. It will be noted also that the distribution of these characters in the second generation (as predicted on the basis of my observation of earlier seasons) was essentially that which has come to be familiar everywhere within recent years as the typical distribution of characters among second generation hybrids in what is now known as Mendelian heredity.

To be sure the figures given are only approximate, nor have I in any of my experiments endeavored to keep accurate count of the precise numbers, the large scale on which I operate making this scarcely practicable—but the close approximation of the rough estimate that I made to the precise figures that have been determined by more recent investigations, sufficiently attests the accuracy of the observations on which the estimate was based.

And, figures aside, the essential principle of the segregation of characters, and their redistribution into three essential groups, one representing each parent, and one combined as in the first generation hybrid, is as clearly stated as can be desired.

The interest of all this hinges solely on the fact that the statement was published in 1898, based obviously on observations made prior to that date; at a time, therefore, when no one living had the remotest knowledge of the discovery made by Mendel more than thirty years before. Mendel himself died in 1884, and the rediscovery of his work was not made until a year or two after the date of my catalog, just quoted.

And I may fairly assume, I believe, that there were few, if any, botanists or plant developers in the world, at the date of this publication, who had any such clear conception of the meaning and interpretation of the prediction contained in the quoted paragraph as my own original observations had given me.

In point of fact, the observation on the seeds of the Paradox walnut, as here quoted, was made quite casually.

I did not put it forward as constituting a new pronouncement in heredity, because it simply represented a specific application of a general truth regarding the tendency of heritable characters to

A Row of Paradox Walnuts

The paradox walnut, it will be recalled, is a hybrid produced by Mr. Burbank, through cross pollenizing the Persian walnut and the California black walnut. The picture shows a row of very young Paradox walnuts growing beside Mr. Burbank's gardens at Santa Rosa.

be segregated and recombined in the second generation hybrids that had come so often under my observation that it had become a commonplace to me many years before the publication of this catalog in 1898.

I have elsewhere stated that the matter had been the subject of controversy with a good many of the leading botanists and horticulturists of the world, and that during the period of perhaps fifteen years prior to the rediscovery of Mendel's experiments, I seemingly stood in a minority of one in the belief that such segregation and redistribution of characters in the second generation hybrids is the usual and all but habitual method of inheritance.

After DeVries and his fellow-workers had come upon Mendel's earlier publication and made it known to the world, the matter was no longer in dispute.

But then the neophytes who had so long refused to listen to my claim were disposed, after the manner of neophytes, to become over-enthusiasts, and some of them at least thought that the principle of the segregation of heritable characters in the second generation was one that must supplant all other principles of heredity, reducing questions of inheritance to such simple formula that the veriest tyro could master them, and having them in

hand, could go into the field and create new forms of plant life at will.

And because I ventured to point out that the essential principles that now came to be spoken of as Mendelian had been the guiding principles of my experiments for at least twenty years before Mendelism was heard of, I was denounced in some quarters as reactionary, the fact being quite overlooked that the essential principles involved had been discovered by me quite independently; exploited by me in connection with many hundreds of species; given publication by me prior to the rediscovery of Mendel's forgotten paper; championed by me against the opposition of all the leading authorities of the world; and that therefore the aspect of heredity in question might with full propriety have been named "Burbankian" instead of "Mendelian", were it not that Mendel's discovery had priority because it was published so long ago as 1863, whereas my independent discovery of the principle was not made until almost twenty years later.

Even at that, however, I had had full twenty years priority over any one else except Mendel in the recognition of the principle.

Therefore, as I just intimated, I have found it a trifle disconcerting to be heralded as reactionary and as scouting the essential principles that I

ardently espoused during a period of at least sixteen years subsequent to the death of Mendel, during which they had no other champion.

What I have deprecated, however, in recent years, is the over-enthusiasm of certain alleged followers of Mendel, who have entertained what I conceived to be a misapprehension as to the real significance of "unit characters", and who, misguided by a narrow range of experiments, and lacking the breadth of view that comes with wider experience, have supposed that all heritable characters might be classified as fixed and unvarying entities that are transmitted in accordance with the Mendelian formula.

Fortunately, a good many former holders of this biased and inadequate view have seen its insufficiency, and already there is a tendency to react from it, evidenced in the writings of some of the leading Mendelians; and, coupled with this, the tendency to take a broader view of heredity and to understand that there are countless heritable characters that do not Mendelize in any tangible or demonstrable way; that "unit characters" are themselves made up of subordinated characters; that new "unit characters" from time to time appear, whereas old ones that at one time Mendelized are finally so fixed that they blend with the older structure of heredity and no longer present the

A Twelve-Year-Old Paradox Walnut

An idea of the size of this tree may be gained by comparison with the telegraph poles and with the man standing in the corner. Were it twice its actual age, it would still be a remarkable tree. Observe the attractive and symmetrical form.

phenomena of "dominance" and "recessiveness"—in a word, that heredity is a somewhat larger term than Mendelism, and that the biologist or botanist or plant developer who would gain a really clear conception of the situation must clearly distinguish between the lesser term and the greater, although at the same time recognizing that one is an essential sub-structure of the other.

So Darwinian heredity, which recognizes the heritability of whole coteries of characters that are too profoundly fixed to Mendelize, is again receiving recognition; and the multitude of special studies of the past decade that were inspired by the rediscovery of Mendel's work and by the exploitation of his formula will take their place as interesting additions to the minutia of the scheme of heredity, without being supposed by any one, except here and there a victim of mental strabismus, to represent the full measure of the great mysteries of inheritance.

We have had occasion in successive chapters to present again and again illustrations of the type of hereditary transmission that lends itself to classification under the Mendelian notation. We shall catch further glimpses of it before we are through. Here it seems worth while, in connection with the story of the hybrid walnuts, to attempt a more comprehensive view of the entire field of heredity,

endeavoring to gain a clear notion as to just what are the underlying principles that determine whether or not a certain heritable character or pair of characters shall Mendelize; and in so doing we may correlate our earlier studies, and secure a clearer notion of the underlying principles of evolution, and of the origin and development of species, than could perhaps have been gained without the aid of the illustrative cases that have been presented.

Natural Selection

In the preceding chapter we briefly reviewed the story of the vicissitudes to which plant life has been subjected in the course of recent geological eras. We were concerned there with the elimination of unadaptable species rather than with the evolution of adaptable ones.

But it should of course be understood that the same principle of natural selection applies to the preservation and to the weeding out of species.

In the case under consideration, it was the changed climatic conditions, through which the northern hemisphere was transformed from a region of tropical heat to one of arctic cold, that resulted in the destruction of countless species, leaving only a tithe of the original number to constitute the flora of the temperate zone in our own day.

It is easy to see how the altered conditions of temperature made the struggle for existence unduly hard for many species, because there is a tangibility about the coming of a glacial period that finds an analogy in the coming of winter in the regular sequence of seasons. The fact that a plant which thrives in the summer in northern regions cannot survive through the winter unless protected is so familiar as to give us a concrete example of the destruction of species through changed climatic conditions in the geological eras.

But the struggle for existence that goes on all about us among plants of every species is so much less tangible that it is not so easily visualized.

Not unlikely the climate of the northern hemisphere is changing now year by year as rapidly as it ever changed in any era of the past.

The alteration is so slight within the span of any single life as to be unappreciable. But when we look back, aided by the studies of the geologist, and think of the change of climate that transformed the flora of the Mesozoic time, we see things clustered in perspective, and in our mental vision the picture of the transformation from tropical to arctic conditions corresponds rather to the onset of winter in our annual experience, than to the true picture of a change of climate that required not merely centuries but millenniums.

In the same way we conceive of the evolutionary changes through which new species were evolved in the past as having been relatively sudden. I have already referred to the difficulty with which the average mind can grasp the idea that precisely the same sort of change in animal and vegetable forms is taking place to-day that has taken place in all other stages of evolution.

It was one of the great merits of Darwin's exposition of the "Origin of Species", that he gave detailed illustrations of the struggle for existence, and brought tangibly before the minds of thoughtful people the conception that each race of beings is more or less in competition with every other race, and that the race that is adaptable enough to adjust itself to new conditions is the only one that stands any prospect of survival.

The idea of the progression of the normal increase of living creatures in geometrical ratio and of the resulting over-population of any territory by the progeny even of a single pair, if there were no counteracting factors, was of course received by Darwin from Malthus. But the application of that idea to all races of animals and plants, and the logical deduction from its application which first made possible anything like a clear understanding of the reason why vegetable and animal races have evolved, was due to Darwin.

A Sixteen-Year-Old Royal Walnut

The royal is a Burbank hybrid between the California black walnut and the eastern black walnut. It rivals the Paradox in its rapidity of growth, and quite outdistances either one of its parents.

Alfred Russell Wallace conceived the same idea independently, and must always be credited with a share in the discovery.

But of course it was Darwin's exposition that gave the subject general vogue, and the scheme of heredity that it connotes is with full propriety spoken of as Darwinian evolution.

The essentials of this scheme of heredity may be stated in a few words, as follows: Animals and plants tend to increase in geometrical ratio. If unopposed, the progeny of a single pair of animals or an individual plant would soon populate and over-populate the entire earth. Opposition to such over-population comes from the rivalry of other animals and plants. The struggle for existence thus induced puts a premium on the individual animal or plant that is better able than its fellows to seek means of sustenance. Such an individual will, on the average, live longer and produce more offspring than an individual less well adapted to its surroundings.

The preservation of these favored individuals and their progeny may be described in a phrase as "the survival of the fittest."

The natural processes that determine such survival on one hand, and the destruction of the less fit on the other, may be spoken of as constituting "natural selection."

This term, natural selection, has obvious propriety because it connotes a process closely akin in its results to the artificial selection through which man determines that certain races of animals and plants under domestication shall be preserved, and that others shall be destroyed. But artificial selection is after all only a phase of natural selection, in which man becomes an active influence or a deciding element in environment.

Because of man's power to transform the conditions of soil, to supply artificial heat, and to bring together and hybridize plants and animals that would not come in contact in the state of nature, the results of artificial selection, epitomizing within certain bounds the results of natural selection, may be produced with unexampled celerity.

Man, for example, eliminates a species in a few decades, where nature would have found no way of correspondingly rapid elimination. The black walnut, for example, has been almost exterminated throughout eastern America because man prized its wood for the making of furniture. But for the presence of civilized man the black walnut would doubtless have maintained its position for ages to come, just as it had maintained it throughout the ages of the past.

Yet we must not forget that on occasion there

may be natural methods of elimination that will single out a species and destroy it as expeditiously and as certainly as man could accomplish that end.

A case in point is furnished by the chestnut, which, as we have seen in a recent chapter, has been singled out in certain regions of the Eastern United States by a fungoid blight that leaves no chestnut alive in the regions over which it spreads. Yet this blight seems powerless to effect any other species.

Here, then, we have an example of a destructive agency of an unpredicted kind that gives an example of the rapid destruction of a species, through natural selection, because that species could not rapidly enough adapt itself to a new condition.

Given time, the chestnut would doubtless develop immunity to the fungoid pest. But time was not given it, and hence it was destroyed.

This present-day illustration perhaps gives as vivid an impression of one of the more tangible ways of the operation of natural selection as could be desired. But we must suppose that such drastic measures as this are rather exceptional and that in general the processes through which species are eliminated are more subtle in their operation, although their ultimate results are no less striking.

Nuts of the Royal Walnut

The Royal hybrid, unlike the Paradox, bears nuts in extraordinary profusion. Moreover, these nuts are of very large size, far surpassing those of the parent forms, as is illustrated in the succeeding picture.

All this has to do, however, with the destruction, rather than with the evolution of species.

I have already said that the principles of natural selection apply with equal force, and seemingly with entire impartiality, to the destruction and to the preservation of species.

But it is obvious that mere preservation of species does not necessarily imply also the evolution of species. Natural selection might give a dominant position to a particular species, and preserve it for indefinite periods without essential change.

But this could only occur in case the conditions of environment themselves remained essentially unchanged.

It is fundamental to a clear understanding of evolution to realize that in a changing environment, under natural conditions, no species could be preserved unless it proved adaptable.

Indeed, the more perfectly adjusted the species might be to its environment at a given period, the more certainly must that species be destroyed should the essential conditions of the environment change.

The great penalty of specialization is the danger that attends it from this source. It is held that the species that were eliminated when the great climatic change occurred to which we have

more than once referred were those that were the most highly specialized.

But, on the other hand, a species that is able to change in such a way as to adapt itself to new conditions stands at least a chance of being preserved, however widely the environment may be altered. And, in point of fact, most species in a state of nature have a considerable measure of adaptability. Individual variation is the universal rule, and such variations are accentuated by natural selection very much as the plant developer accentuates them by artificial selection. So the plants and animals in a state of nature are plastic material, and under changing conditions of environment which represent probably the usual and normal condition of things, they are constantly, even if slowly, being modified. And of course such modifications, when they have been sufficiently added to, alter the character of the species altogether.

Which is only a detailed and roundabout way of saying that species are evolved and transformed into new species under the influence of natural selection.

But whoever considers this matter attentively will come presently to realize that in any such analysis of the operation of natural selection in the evolution of species as that just suggested,

there is an underlying assumption to the effect that the various modifications of the individual are transmitted to the offspring of the individual.

Unless such is the case, it is clear that there could be no such thing as the evolution of new species. It would avail nothing for the progeny of an individual that this individual was well adapted to its surroundings, unless the said progeny inherit the characteristics that made such adaptation possible.

There is no logical escape from that conclusion. Whatever our conception of the mechanism of heredity, or of the exact manner in which the transmission of variation occurs, no one can be an evolutionist who does not believe that acquired characters are transmitted through heredity.

There was a school of biologists who gained great prominence a few years ago, who denied the possibility of the transmission of acquired traits. Throwing logic to the winds, they based their denials on a metaphysical interpretation of certain observed microscopic structures within the germ-cell. These same biologists, while denying that acquired traits could be transmitted, were at the same time ardent upholders of what they called Darwinian evolution.

But such a paradoxical contention must of necessity fail to maintain itself for any consider-

Hybrids and Parents

At the left, a nut of the California black walnut (Juglans Californiaca), the staminate parent; in the center a nut of the eastern black walnut (Juglans nigra), the pistillate parent; at the right a nut of the Royal hybrid, all shown in natural size. It will be seen that the hybrid nut is fairly intermediate between the parent forms in its general appearance, but that it greatly surpasses either of them in size.

able period. In the last analysis, people are able to put two and two together and discover that the result is four. And in the course of time even the most illogical biologists were forced to see the elemental truth of the proposition that new characters acquired by an individual organism must be transmissible, else there could be no such cumulative change as that which results in the transformation of a species in new adaptations to its surroundings.

In other words, if acquired characters are not transmitted, there can be no organic evolution.

But a good many of the former adherents of this paradoxical view have abandoned their illogical position unwillingly, and even now are only willing to admit that such acquired characters are transmissible as are imprinted first on the germ plasm, and not on the body of the parent organism.

The contention really reduces the entire matter to a question of definition. It is virtually a distinction without a difference, when we reflect that, at all events, in the case of the plants, germ plasm and body plasm are everywhere associated, so that we must suppose that if there is really a distinction between the two, it is a distinction within the substance of the individual cell, as the plant body contains both body plasm and germ plasm. Our earlier studies have shown that we are forced to

this conclusion; and obviously if this interpretation of germ plasm be accepted, it is a mere quibble as to whether the change or modification of an individual plant involves primarily the germ plasm or whether it involves the body plasm of the same cell as well.

Of course such mere incidental modifications of an individual as have to do with injury of its parts, the laceration of tissues, or the like, cannot be supposed to have any influence in heredity.

If such accidental modifications are heritable, the entire scheme of inheritance would become chaotic.

The modification that *is* heritable must be one that involves the constitution, so to speak, of the plant; such modification as would be brought about by changed conditions of nutrition, or by an altered temperature. A certain amount of experimental proof is already in hand that such modifications as these may be inherited. And if the opponents of the theory of the transmission of acquired traits can get any comfort out of the claim that such modifications directly effect the germ plasm, we need not wish to rob them of that cold comfort.

Details as to the special manner of inheritance aside, we may accept it, I think, as the only logical conclusion from a wide survey of the facts of her-

edity and evolution, that all modified characters that effect the constitution of the individual are heritable. Even the slightest modification of structure due to altered nutrition, to changed temperature, or the like, probably makes its influence felt on the next generation in exact proportion to its value in the great complex scheme of characters with which it is associated.

But this statement must not be misinterpreted. It must not be supposed that any minor modification of an individual can influence, except in an infinitesimal way, the inheritance of the offspring of that individual.

For the new modification will be, in the nature of the case, only as an alien drop or two in an ocean of hereditary tendencies.

Or, stated in somewhat more modern terms, the hereditary factor that represents the new modification will be as one minor factor among thousands or perhaps millions of pre-existing factors.

If we revert to an earlier illustration, in which we thought of the germinal nucleus as a piece of architecture made up of multitudes of factors of heredity, we may think of the new factor as one added brick in a structure of palatial proportions, made up of thousands of bricks.

Yet it is by the cumulative effect of such minor modifications, we may well believe, that evolution

has been brought about, and that in the long lapse of ages, the highest forms of existing plants have been built up by successive stages of inheritance from the lowliest single-celled organisms.

The Status of Mendelism

In the large view, then, whereas it will be recognized that all acquired traits have their influence in heredity, yet it will also be recognized that the vast sum of qualities that are of less recent origin has preponderant influence, and that the racial characteristics as a whole are overwhelming in their power as against any individual modifications.

Yet, to complete our picture, we must recognize also that nature is not conservative, as she is commonly said to be, but is highly progressive. It could not be otherwise, in a world in which the natural environing conditions are constantly changing.

The basal law of evolution, as we have seen, is that the unchanging, the conservative organism, is doomed. It is only the progressive, the changeable, the plastic organism that can hope to maintain itself and perpetuate its kind indefinitely.

The price of specific life is that the species shall not maintain its identity.

And this interpretation of the situation gives a clew, so it would seem, to that important and inter-

A Typical Specimen of the Royal Walnut

This splendid tree grows beside a fence in Mr. Burbank's experiment garden at Sebastopol. Note the symmetry of form, the wide spread of limbs, the luxuriance of foliage, and the general aspect of vigor.

esting aspect of heredity to which we referred at the beginning of this chapter—the phase commonly spoken of as Mendelism. The essential characteristic of this aspect of heredity, as we have pointed out over and over, is that heritable characteristics are transmitted in a sense independently one of another, in such a way that they may be segregated and put together again in new combinations in successive generations.

The detail within this scheme of transmission, with which Mendel himself was chiefly concerned, and which absorbed the attention of his followers until it was found that there was need of taking a wider view, was involved in the phenomena of dominance and recessiveness. Mendel found, for instance, as we are aware, that when a tall pea vine was crossed with a short one the hybrids of the first generation were all tall, because, as he said, tallness was dominant and shortness recessive. And in the second generation one-fourth of the vines were short because the factors for shortness were segregated, according to the theory of chances, and one-fourth of the vines were pure recessives.

The fact of such dominance and recessiveness between pairs of heritable characters is too obvious to escape attention of any careful practical experimenter, now that attention has been called

to it. But it is equally obvious that there are vast numbers of other heritable characters regarding which no such clear matching as to dominance and recessiveness is observed to take place.

And so the early enthusiasts were led finally to see that Mendelian dominance and recessiveness apply only to a certain small number of hereditary factors in the case of any individual plant or animal.

They came presently, after much heated argument, to admit that dominance and recessiveness constitute after all only a minor aspect of Mendelian heredity.

Yet this aspect of the subject, even if not all-important, has obvious interest. And the question naturally arises as to which ones among the numberless hereditary factors in the case of any given organism will "Mendelize" in this sense, and why these factors will thus Mendelize while others fail to do so.

The answer is found, apparently, in the simple assumption that the factors that show the phenomena of dominance and recessiveness are those that are relatively new acquisitions in the germ plasms of the species under observation. Traits that have been the common heritage of the ancestry for untold generations, constituting the fundamental structures of the organism, do not Mendelize. They

have proved their merit, and are accepted as part of the necessary equipment of the plant, not subject to the testing process that Mendelism essentially constitutes.

Such fundamental structures are, for example, the root and stem and leaves and stamens and pistils of a flowering plant. As to their broad essentials of form and structure, these fundamental organs are inherited *en bloc,* and never jeopardized by being weighed in the Mendelian scale.

But the newly acquired characteristics, such as details of leaf form, or color of petals, or size and quality of fruit—these are matters that are subject to modification because they have not as yet established themselves as fundamentally necessary in any detail of form or color to the species. These fall within the scope of Mendelian testing.

For hundreds of thousands of years, doubtless, the progenitors of plants that now have flowers were provided with roots and stems and leaves, and with essential reproductive organs, but had no blossoms. In comparatively recent times the blossoms were developed. And the modifications of color of the blossoms in the case of any given species are, as we have found reason to suppose, of still more recent origin.

These modern details, then, and their like, are the ones that are subject to variation and that are

still matter for change and adaptation; still in the experimental stage, as it were. And precisely because such is their status, these are the things that are subjected to the Mendelian test when they are brought in juxtaposition, through hybridizing, with forms that differ as to these details.

And as only the relatively new structures Mendelize, so it is the newer member of any pair that assumes prepotency or dominance. Contrariwise, the older member is recessive.

Students of different examples of Mendelian heredity, as applied to animals and plants, have puzzled long to discover the underlying principle that determines which character shall be dominant and which recessive. But this simple principle appears to furnish the explanation.

The new trait or characteristic is dominant over the older one precisely *because* it is new.

By making it dominant, nature gives it the best possible chance. It will reproduce itself in all the immediate progeny of the individual that possesses it. Thus nature shows anew that she is progressing. She accepts the new characteristic and gives it more than an even chance.

But at the same time she is not so foolish as to renounce the old character without full testing. She allows it to be subordinated for a generation, but in the next generation it reappears, isolated, to

The Royal Walnut in Winter

This is the same tree shown in the preceding picture, photographed after it had shed its leaves. Observe the size of the trunk, in comparison with the man's body, and the straightness of trunk, indicating a large quantity of lumber. The wood itself has the good qualities of the black walnut, being hard and durable, and susceptible of taking on a fine polish.

compete with the dominant character. And whether in the end the new dominant character will prove itself and prevail, or whether the recessive character will re-establish itself, depends entirely on the value for the species of one character as against the other.

Mendelian heredity, then, is a testing out process for new characters. It is, as it were, the skirmish-line of the advance guard of evolution. So long as a character is subject to Mendelian transmission, showing the phenomena of dominance and recessiveness, it is a relatively new and unfixed character still on trial.

And in proportion as any character has proved itself and has passed the trial stage, it becomes blended with the hereditary factors that have more stable position, just as conscious acts of the individual become instinctive or reflex when often enough repeated.

In this view, then, the so-called unit characters that Mendelize are, as was said before, merely the fringe to the great fabric of heredity. They serve the plant developer an admirable purpose, and, indeed, it is with their manipulation that he is chiefly concerned. Their relative insignificance is evidenced in the fact that the plant developer cannot possibly produce major modifications in the organisms with which he deals.

He does not attempt to make squash vines into oak trees, or blackberry briers into tomatoes.

He recombines those newer, and hence less important, structures and qualities of which the fact of their Mendelizing is adequate proof of their newness and relative unimportance. If he would get beyond this and create really new forms, adding something to the plant that no ancestor of the plant ever had, he could hope to do this only if a term of life were granted him that would be measured not in mere years but in millenniums. For evolution is a slow process, and the history of the development of natural species is measured in geological eras.

Selection and Mendelism

Perhaps it may be worth while to illustrate this matter a little more in detail, that we may make clear precisely what manner of thing the plant developer is doing when he produces a new race by selection.

We have stated over and over that the process of hybridizing and the process of selection are complimentary. One supplements the other. In hybridizing we make possible new combinations of the hereditary factors, and in selecting through successive generations we isolate certain definite combinations, and thus produce what we call new varieties. Now it is frequently stated by the ex-

perimenters who have paid attention only to a few conspicuous characters that Mendelize, that all possible combinations of characters will occur among the second generation hybrids, provided only enough of these are produced.

Possibly this statement is correct. But it is not susceptible of demonstration because it would not be feasible to produce enough individuals in a single generation to put it to the test. For the number of possible combinations increases in geometrical ratio, as we have seen, with the increased number of characters under consideration. And a really penetrating view of the situation reveals to us hereditary factors in the germ-plasm of each individual plant that would be numbered, could we isolate them, not merely by tens or scores; not merely by hundreds or thousands; but rather by hundreds of thousands or millions.

Such a statement probably will not surprise any one who has read the various preceding chapters in which we have viewed various aspects of heredity. But to those experimenters who have been prone to think of "unit characters" as few in number, such a statement will perhaps seem anomalous. Yet there can be no question that it is fully justified.

In point of fact, what the present day student of heredity usually speaks of as a unit character

might better be referred to as a "unit complex," or by some allied term that would suggest its complicated character. The word "gene-complex" has been suggested in a similar connection.

It would appear that the real purpose of selective breeding through many generations is to remove one after another of the factors that dominate or mask other factors, so that subordinate or recessive factors may make themselves manifest.

No one who has experimented widely will doubt that it is possible by a series of selections extending over several generations to accentuate a given character, say to bring out the crinkled formation of the poppy petal, or the corrugations in the leaf of a wild geranium, or an added row of petals in a balloon-flower. And it goes without saying, that, according to the modern terminology, the character thus isolated must be represented by an hereditary factor which was present in each successive generation utilized in our experiment, but which for some reason was not enabled to make its influence so potentially felt in earlier generations as it was in later ones.

And the only logical explanation appears to be that in each successive generation of the plants carefully selected and inbred, there was a new redistribution of factors, always along Mendelian

Another Fine Specimen of the Royal Walnut

This magnificent tree, one of the first seedlings of the Royal walnut, stands in a dooryard beside the Sebastopol road, near Santa Rosa. It bears mute but eloquent testimony to the success of one of Mr. Burbank's early experiments in hybridizing forest trees.

lines, which isolated, in the case of the individual we selected, the particular character which we had under observation more and more completely.

Whereas, in a simple case of Mendelian heredity, where one pair of factors is in mind, there is complete isolation of the recessive factor in one case in four; in this complex case there is isolation of groups of factors, and in one case among thousands there may occur such relatively complete isolation of the factors for quality we are seeking as will serve our purpose. Such isolation might occur in the second generation, but it cannot be counted on to occur until we have tried again and again, in each successive generation, using material that is a little less complex because a certain number of disturbing factors have been segregated and removed.

We may perhaps illustrate the meaning of all this a little more clearly if we suggest that each so-called unit character with which Mendelian heredity deals is in reality made up of a thousand factors. I do not mean to imply that the number is just that; it is merely that a thousand is a convenient round number for purposes of our computation.

There would be, then, a thousand factors for color combined to make up what we commonly speak of as the unit factor for color; there would

be a thousand subordinate factors for form of flower; a thousand others for texture of petal; a thousand others for odor; yet another thousand for hardiness; and so on for each and every patent characteristic of flower and twig and stem and root of the plant. In the aggregate, let us say, there are a thousand different "unit characters," each made up of a thousand minor factors, so that the total number of hereditary factors stored in the germplasm and fighting for recognition, in the case of a single plant, is a round million.

Each of these million factors has been developed in the long slow process of evolution, one after another added, generation by generation, or era by era, beginning with the time when the remote primordial progenitor of the plant was a single-cell organism.

In the course of the ages, development has taken place along divers lines, and it has come to pass that certain combinations of hereditary factors have been grouped into systems that have so long been working in harmony together that they cannot be separated. The members of one such group determine the architecture of the root; the members of another group determine the architecture of the stem; and so on for each of the patent characters.

But there are other groups of factors that are

Foliage and Fruit of the Royal Walnut

The foliage of the eastern and western black walnuts is very similar, and the foliage of the Royal hybrids may be said to bear close resemblance to that of both parents. It is grown in extreme profusion, however, as this picture shows, in keeping with the very great vigor and fecundity of the tree.

less ancient in their origin. There were some that made their way into the germ plasm of the ancestors of the plant so recently as half a million years ago. There are others that are more parvenus of perhaps ten thousand years. And there are yet others that are upstarts of literal yesterday.

Each one of these hereditary factors is striving for recognition and endeavoring to make tangibly manifest the condition or quality or form or constitution of tissue that it specifically represents.

And, according to the view just presented, the thousand factors that make up any given complex stand in such sequential relation to each other that each successive one controls in a measure its predecessor in point of time, and is controlled by its successor. The very newest factor that has been admitted to the coalition has a more powerful influence than any other *single* member of the coalition.

But meantime this most powerful individual is after all only one among a thousand.

In a company of a thousand men, some one man is stronger than any other. But this strongest individual would be infinitesimally week in comparison with the combined strength of the other 999.

This is the important thing to bear in mind. The newest member in each of the thousand or so

hereditary "complexes" that we speak of as unit characters is the most powerful individual factor. But, inasmuch as the great body of antecedent factors are using their influence in unison in another direction, it is inconceivable that the influence of the single new factor should greatly change the aggregate result.

In this view, what we term a species is a company of organisms in the germ plasm of which the groups of factors for each main characteristic have become purely and unqualifiedly recessive, so that they act as a unit in producing a given character. They thus determine the chief characteristics of heredity in the Darwinian sense, which finds its popular expression in the phrase "like produces like."

Meantime, there are always minor groups of newer characters that are fighting for recognition, and while these are relatively insignificant because of their newness and small number as compared with the whole, yet they are conspicuous and important in the eyes of the plant developer because they represent precisely those modifications of form and constitution and color that mark what we speak of as variations from type; and because they are so matched against one another in heredity—in the manner that we call Mendelian—as to make it possible for the plant developer to segregate and

A Striking Contrast in Seedlings

Here are two seedling hybrid walnuts of the same age, grown from nuts of the same tree, and having had precisely the same care. They are second-generation hybrids, hence the wide variation in size and vigor of growth. One of these plants will grow into a gigantic tree; the other will remain dwarfed always. Obviously there are fine opportunities for selection among the seedlings of the hybrid walnuts.

recombine them variously by hybridizing, and thus to develop new races from the old stock.

When, however, the plant developer, through his hybridizing experiments, brings together groups of characters in which the old guards, so to speak, that have control over the fundamental characters are in conflict, no union is possible.

Either fertilization will not take place, or the offspring will be sterile. Only within narrow limits, and as regards the new and relatively unessential characters, can there be diversity or, at most, the accentuation of old characters.

Such an accentuation, for example, occurs, we may suppose, in the case of the hybrid walnuts, which take on gigantic growth. Both Persian walnut and California walnut have in their germ plasm the hereditary factors of large groups of remote ancestors of the Mesozoic era, when gigantism was the fashion, but these factors have for long generations been subordinated by newer ones born in a less favorable era. Now, however, hybridzation brings the two strains together, and the two dominant groups of factors for slow and relatively dwarfed growth, in some way mask or neutralize each other, enabling the earlier groups to make their influence felt.

And here, as we have seen, the factors for growth that have thus been rudely disturbed as to

their hitherto harmonious coalitions, are reassorted in the second generation, as united groups acting along Mendelian lines, so that part of the progeny of the second generation are giants, and part of them are dwarfs, and that all manner of intermediate forms find recognition in the case of different individuals.

In no other way known to us could such a disturbance of the coalitions of hereditary factors have been brought about. So the plant developer who thus brings together racial strains that have been long separated introduces a disturbing element that in its practical effects may produce such modifications as could only be produced otherwise through the aggregate influences of environment for almost numberless generations.

But let it be repeated that even when the hybridizer effects such a disturbance as this, he can do no more than to enable subordinated hereditary factors to make themselves manifest.

He is dealing with material that has been brought together through age-long experiments, and even though the new combinations that he effects may be striking ones, he may rest assured that even his most spectacular achievement is but a feeble replica of plant developments with which nature has experimented thousands of times over in the course of the long evolutionary ages.

Tapping the Rubber Tree

This primitive method of tapping the rubber tree will insure a large flow of sap, but will also endanger the life of the tree itself. In the cultivated orchards, the rubber tree is tapped in a more conservative manner, avoiding injury of the tree. But of course the principle involved is everywhere the same.

Trees Whose Products are Useful Substances

From the Sugar Maple to the Turpentine Tree

EVERYONE who had the good fortune to be born in New England and to live in the country will treasure among the most pleasant reminiscences of his boyhood the recollection of his first visit to a "sugar bush."

The sweet sap drawn through a magic spigot from a hole in the tree trunk; the boiling pot in which the sap was transformed into the most delectable of syrups; the transformation of the syrup into a wax of quite matchless flavor by pouring it on the snow—these are things that have no counterpart. They must be experienced to be appreciated, and no one who has experienced them is likely to forget them.

To the unfortunate who has not been privileged to visit a sugar bush, the product of the maple is usually known only in its ultimate crystallized form in which it constitutes a brownish sugar of

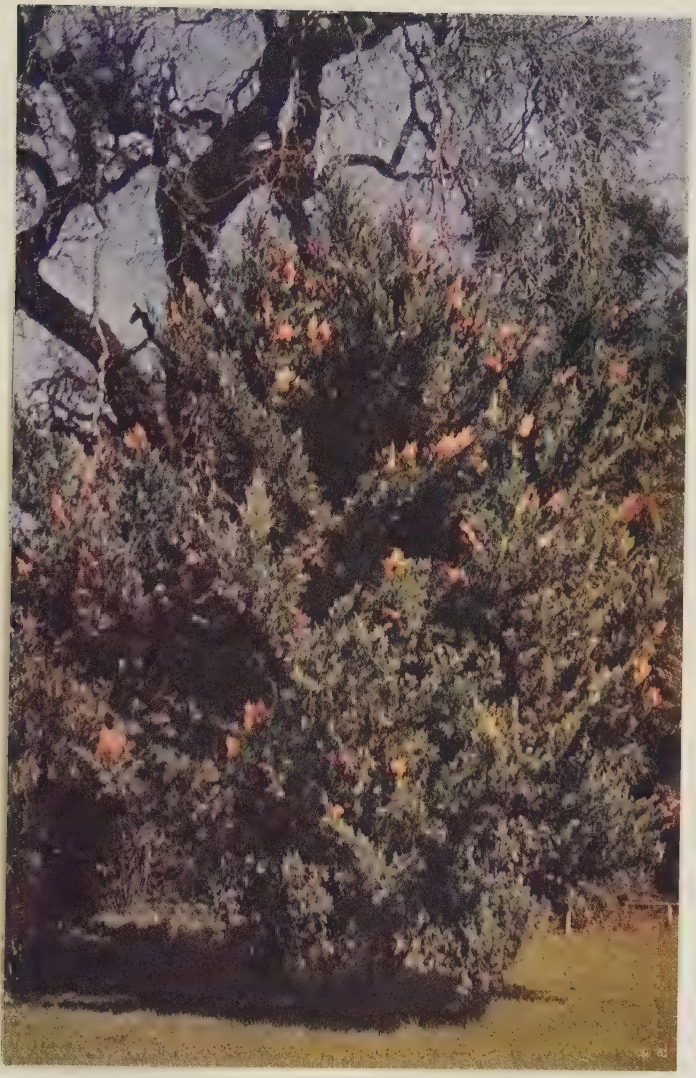
characteristic and delectable flavor. And I regret to say that many people who suppose themselves familiar with this product know it only in a diluted and adulterated form in which only a suggestion remains of the real maple quality.

Nor does there seem to be much prospect of improvement in this regard, for, so far as I know, the maple tree is seldom or never cultivated for the garnering of its unique crop. The relatively small quantity of maple sugar that finds its way to the market is the product of trees that chanced to grow in the woodland and they are reserved not so much as sugar producers but as ultimate material for lumber. Yet maple sugar is a sweet of acknowledged quality, and one that deserves a larger measure of recognition as a commercial product than has hitherto been given it.

Possibly the time may come when maple trees will be set out and cultivated for the production of sugar. But it is hardly likely that such cultivation of the maple can ever constitute a significant industry, because the product of a single tree is relatively insignificant.

It is only the fact that the sugar maple has wood of such quality of fiber as to make it valuable for the cabinetmaker that could justify the cultivation of these trees as a commercial enterprise.

On the other hand the amateur orchardist



A Fir Tree

Just as the tropics have their gum producing plants, such as the rubber tree, so do the temperate and arctic zones have their gum producers in the firs and pines and other evergreens. The tree shown here is a fir which Mr. Burbank is observing by reason of the quantity and quality of its exudate.

might do far worse than to set a row of maples, as ornamental trees about the borders of his orchard or gardens, regarding the capacity of the tree to produce a certain amount of sugar as an incidental attraction that adds to the value of a tree that otherwise is deserving because of its beauty of form and general attractiveness.

The production of the sweet sap that has made the sugar maple famous gives this particular species exceptional interest among the members of a very meritorious family. Just why this species should have developed the capacity to produce so sugary a sap in such abundance, it would perhaps be difficult to say. A certain amount of sap may be drawn from the tissues of other maples, and even from the walnut and butternut, and in diluted form from the birches; but only the sugar maple produces sap of such quality as to be of real value.

When the Sap Runs Best

And of course it is well known that the sugar maple itself has a "flow" of sap that is worth tapping, for a very brief period each season, just as winter is merging into spring. It is traditional at least among the makers of maple sugar that the sap runs best in those days of early spring when the sun shines brightly while there is a coverlet of snow on the ground. At this time, all that is neces-

sary is to bore an auger hole in the trunk of the tree, and insert a spigot or grooved stick to guide the sap into a bucket.

A single tree may be tapped in several places, and a bucket of sap will run from each spigot in the course of the day.

The sap itself is a clear, watery fluid, the sweet taste of which gives assurance of the quality of the sugar it contains. By boiling the sap to evaporate the surplus water, a thick syrup is produced which crystallizes on cooling, producing the maple sugar of commerce.

Nothing is added to the sap and nothing but part of its watery content is taken away from it—that is to say, if it is honestly made. The sugar as the maple supplies it, is a perfect product requiring no diluent and calling for no elaborate process of manufacture.

Perhaps it is not so much matter for surprise that maple trees produce this sweet sap in such abundance as that other trees do not more generally imitate its example. For the function of the sugar in supplying nourishment for the young buds before the leaves are sufficiently expanded to begin their work of sugar manufacture is clearly enough understood. All other deciduous trees must supply nutriment in similar way to their growing buds.

But in the case of other trees, either the sap

A Spruce Tree

The spruce is one of the most familiar and most highly prized of evergreens in many of our northern forests. Its resinous exudate was formerly very popular as a commercial product known as "spruce gum." Nowadays the demand for chewing gum has so increased that it has been necessary to find other materials for its manufacture, and the once-familiar spruce gum has practically disappeared from the market.

will not flow in abundance or it is of such quality as to have no value.

The manner of production of the sap may be more or less accurately inferred from what we have already learned of plant physiology. We know that the leaves of the tree metamorphose water and carbon into sugary substances which in turn are transferred to various parts of the plant to be stored, usually in the form of starch. In the case of the maple, we may assume that the carbohydrates, as they are manufactured in the leaf-laboratories, are transferred in the current of sap that flows downward from the leaves through branches and trunk as a countercurrent in the cambium until it finally finds its way to the roots of the tree and is there stored for the winter.

When spring comes and it is time for the new leaf buds to put forth, the supplies of nourishment are retransformed into soluble sugars, dissolved in the water that is taken in by the rootlets, and transferred from cell to cell and along the little canals in the wood under the cambium layer of the bark, until they reach the twigs where the leaf buds they are to nourish are located.

It is doubtless the so-called "root pressure" (which we have been led to interpret as due to osmosis) forcing the sap upward that causes it to flow from the wound in the tree made by the

auger. To what extent the interference with the supply of nourishment that was being convoyed to the buds retards their development, might be interesting matter for observation.

But this is something that does not greatly concern the sugar maker, and to which he doubtless never gives a thought.

It is also interesting to conjecture whether it might be possible by selective breeding to produce a variety of sugar maple that will furnish sap in exceptional quantity and of unusual quality. The case is obviously different from that of the sugar prune or the sugar beet, both of which have been trained to increase their sugar content.

But there is no doubt that different individual sugar maples differ widely in their sap producing, or at least in their sap rendering, quality. Presumably the difference may be due to the size of the root system. But so far as I know there are no accurate observations on the subject, nor has anything been done to determine whether a better race of sugar maples could be developed.

Other Plant Juices

The extraordinary plant laboratories that manufacture sugars out of water and air is capable of transforming these sugars into many unusual substances, differing in character with the constitution of the particular plant.

Olive Trees

Until somewhat recently the olive has been grown chiefly in the region of the Mediterranean. Of late years, however, it has become a very important commercial crop in California, and the California olives have become famous everywhere for their size and good qualities in general. The picture shows a typical hillside olive orchard.

There are certain classes of juicy exudates, however, which appear to have characteristics that make them useful to plants of many types. Prominent among these are the milky juices that when dried constitute rubber, and the resinous ones that constitute tars and resins and turpentine.

Nothing could be physically much more dissimilar than a piece of rubber and a teaspoonful of oil of turpentine.

But the chemist tells us that each of these substances is composed exclusively of the two elements carbon and hydrogen; the only difference being that the turpentine molecule has 10 atoms of carbon and 16 of hydrogen, whereas the molecule of rubber has 8 carbon atoms and 7 atoms of hydrogen.

Just how the elements are compounded, and just why they should make up substances of such unique characteristics when brought together in these particular proportions, even the chemist does not know. Nor, until recently, was he able to duplicate the feat of building up these complex molecules, even though he is perfectly familiar with the general properties of the atoms of both carbon and hydrogen.

In very recent years, however, chemists have been at work on the problem of compounding the atoms in such a way as to get them together in the

right combination to produce organic substances. And, although this work is only at its beginning, a good measure of success has been attained.

In particular, the chemists of Germany and England have recently succeeded in combining carbon and hydrogen in the proportion of 8 atoms of the former to 7 of the latter and thus have produced an artificial rubber that is not merely an imitation rubber but is as truly pure rubber as if it had been produced in the cellular system of a plant.

Indeed, the artificial product may be said to be somewhat more pure than the natural, inasmuch as the latter is more or less contaminated by extraneous products.

Reference has elsewhere been made to the familiar feat of the chemist through which the famous dyestuffs, indigo and madder, have been manufactured in the laboratory, and manufactured so cheaply as to compete successfully with the natural product of the indigo and madder plants. What was a large plant industry only a few years ago has thus ceased to have importance. The indigo plant is still cultivated in the east, but the entire industry has been changed by the discoveries of the chemist.

Only a few years ago a plant known as the tar weed (Madia), to which we have had occasion to

Turpentine Trees

There are many of the evergreens that produce resinous exudates allied to turpentine. But the trees that produce the chief supply of turpentine of commerce are the sea pine, the Scotch fir, the Norway pine, and the Corsican pine in Europe, and the swamp pine and the so-called loblolly in the United States. The swamps of North and South Carolina and Georgia are the chief source of supply of commercial turpentine in this country.

refer in another connection, was gathered and its juices extracted for the making of the pigment madder. But it would not pay to undertake this work now, since the chemist has learned how to make madder from coal tar and hence has substituted for a plant industry an enterprise associated with the manufacture of gas.

It will doubtless be a long time before the manufacture of artificial rubber makes corresponding encroachments on the industry of manufacturing rubber from the plant juices. Still it is quite within the possibilities that this may come to pass in the course of the coming generation.

In the meantime, the rubber industry is a vastly important one, and the principal trees that supply the juices that on evaporating constitute rubber are cultivated in vast plantations in various tropical regions. Moreover rubber is gathered from wild trees of several species, although in recent years the cultivated trees have largely been depended upon to meet the growing needs of the industry.

Trees of the genus *Hevea* are the most important source of rubber. But there are many other trees, the juices of which contain the essential constituents of rubber in the right combination, and a good many of these have commercial possibilities.

I have referred in another connection to my

experiments with tropical plants of the genus *Asclepias,* relatives of the familiar milkweed.

I have undertaken tentative experiments to discover whether these plants might be developed to a stage that would make them commercially valuable as producers of rubber. The recent discoveries of the chemist make experiments in this line somewhat less valuable than they hitherto seemed. Yet the demand for rubber is so great, in these days of electricity and automobiles, that there seems little danger of overstocking the market. And if a plant could be developed that could be grown in temperate regions, and they would produce the rubber-forming juices in adequate quantity, such a plant would constitute a very valuable acquisition for a long time to come, even should natural rubber ultimately be supplanted by the laboratory product.

The method of gathering the so-called latex, or milky juice, which is virtually rubber in solution, is curiously similar to the method of obtaining the sap of the sugar maple. Indeed the latex may be drawn in precisely the same way, by boring a hole in the trunk of the rubber tree and inserting a grooved stick along which the juice will run into a receptacle. But the cultivators are not usually content with so slow a method, and there are various methods of tapping the tree that expose a

Balsam Fir Tree

This tree produces a resinous exudate that is peculiarly clear and transparent, and is known in commerce as Canada balsam. This transparent gum is highly prized by microscopists for the embedding of miscroscopic sections and specimens of various kinds.

larger surface of the cambium layer and thus extract the milky juices in larger quantity.

In the case of the wild trees it is not unusual for the natives of Mexico, Central America, and South America to make a series of "V" shaped incisions in the bark of the tree, placing a receptacle at the point of each "V" and thus securing a relatively enormous amount of fluid regardless of the fact that they jeopardize the life of the tree itself.

Of course cultivated groves or plantations are tapped in a more conservative way, but the principle involved is everywhere the same.

The latex of the rubber tree is comparable to the sugary sap of the maple. It appears to be a mere accident that this juice has the property of coagulating to form the substance called rubber which we now find so important. But this substance, obviously, as man uses it, has small place in the economy of the plant. Coagulated latex would serve no better purpose in the tissues of the rubber tree than would coagulated blood in the veins of a human being.

Oils and Resins

Of course the latex of the rubber tree might exude when the tree received an accidental injury, as from a falling limb, and in such case it would be advantageous to the tree to have the juice coagulate, just as coagulated blood is useful

to a wounded man. In each case coagulation prevents excessive hemorrhage.

Possibly this may explain the quality of the latex, its capacity to coagulate having been developed through natural selection. But under normal conditions, at least, the latex is always fluid, and its properties are little more like those of rubber than are the properties of the maple tree like those of sugar.

Of course the same thing is true of the plant juices that when dried or partially evaporated constitute the various gums and resins. As manufactured in the tree they are transformed sugar products, and they are always in solution. Only when the juices are exposed to the air, as when they exude from an injured surface, do they coagulate to form the gummy or resinous substances that become articles of commerce.

In some cases the exudate may be separated into two or more commercial constituents. Such is the case with the juice of those trees that produce turpentine. The liquid that flows from the tree, corresponding to the sap of the maple and the latex of the rubber tree, may be evaporated or distilled in such a way as to be changed in part to a solid gummy or even vitreous substance, and in part to the somewhat volatile fluid familiar as turpentine.

A "Sugar Bush"

The sugar maples have been tapped by boring a little way into their trunks with an auger, and inserting a spigot. The clear, sweet sap is collected in buckets, and subsequently "boiled down" until it crystallizes to form the familiar and delectable maple sugar of commerce. If the sugar is honestly made, nothing whatever is added to the sap.

Turpentine, unlike rubber, was known to the ancients, and was an extensive article of commerce in classical times. The original tree from which it was obtained is known as the terrebinth tree. It is a native of the islands and shores of the Mediterranean and western Asia.

There are many trees, however, the sap of which has this resinous property, including most members of the family of conifers. The principal supply of crude oil, or common turpentine, in Europe, is obtained from the so-called sea pine, grown largely in France. The Scotch fir, the Norway pine, and the Corsican pine are other sources. In the United States the swamp pine and the so-called loblolly trees that grow in the swamps of North and South Carolina and Georgia, are the chief source of the commercial turpentines, although various other species are more or less utilized.

A turpentine of peculiar quality that is highly prized for some industrial purposes is obtained from the balsam fir (*Abies Balsamae*), and is known as Canada balsam.

Hitherto, the producers of turpentine have been found in the wild state, and no one, probably, has given a thought to the possibility of developing races of pines that produce an exceptional quantity of the resin- and turpentine-forming juices.

But with the modern tendency to apply scientific methods to forestration in general, doubtless the question will ultimately arise as to whether the turpentine trees may not be improved along with the timber producers.

That trees of the same species differ quite radically in the amount of the valuable juices is certain, so there would appear to be no reason why it may not be possible to develop varieties of trees that will be conspicuous for this quality, just as other trees have been improved as to their powers of growth or their capacity to produce abundant crops of fruit.

Varied Products of the Plant Laboratory

An incidental use of the resinous exudate of the pine tree that has come to assume considerable economic importance is the production of chewing gum.

The habit of gum chewing appears to have originated or at least to have gained chief popularity in America in comparatively recent times. The resin that exudes from the spruce was the substance that was chiefly used, under the name of spruce gum, until somewhat recently. But of late years the chewing gum industry has reached proportions that make it impossible to meet the demand from this source. And it has been found that ordinary resin, combined with sugar and lin-

A "Weeping" Birch

This beautiful tree stands beside Mr. Burbank's cottage on his experiment farm at Sebastopol. The birches are very hardy trees, and they merit a place in every park and garden; those with white bark in particular furnishing a striking and picturesque contrast to other forms of shrubbery.

seed oil, with some flavoring added, serves the purpose of the original spruce gum so the latter is now seldom seen in the market. More recently chicle, a gummy substance which exudes from several tropical trees, has been imported in great quantities, and is now supplanting all other sources of gum.

The supplying of turpentine and its products gives the conifers high range among trees that produce commercial by-products of great importance. But with the exception of the pines, the trees that produce really important exudates or oils or chemicals are indigenous to the tropics, or at least are confined to the warm temperate zone. I have thought many times in recent years that I should like to have a plant laboratory in the tropics for the testing of tropical plants as to the production of useful commercial products, and for the development of improved varieties of plants the products of which are already utilized.

It would be worth while, for example, to make very extensive experiments by way of testing the qualities of the different trees that deposit in their bark the bitter compound known as alkaloids, a galaxy of which are prized for their medicinal properties. These are very complex combinations of carbon, hydrogen, oxygen and nitrogen. That is to say, they have the same constituents as proto-

plasm itself and they differ from the gum and resins that we have just been considering in that each molecule contains at least one atom of nitrogen.

The sugars, it will be recalled, occupy an intermediate place, inasmuch as they, unlike the resins and rubber, contain oxygen; but they contain no nitrogen. The formulae given by the chemist for the different alkaloids are intricate but they differ from one another only in the matter of a few more or a few less atoms of one or another of the four constituents of which they are all made up.

There is, for example, only the difference of one atom of carbon and of four atoms of hydrogen between a molecule of quinine and a molecule of strychnine. Considering that the molecules comprise in the aggregate not far from fifty atoms, in each case, this discrepancy seems trifling. That the two drugs should have such utterly different effects upon the human system is a mystery that will be solved only when a much fuller knowledge is gained as to the physiological processes than anyone has at present.

But the plant developer, of course, has no concern with this aspect of the subject. What interests him is the knowledge that different races of cinchona trees, for example, are known to vary greatly as to the proportion of commercial alka-

A Branch of the Paper Birch

Here catkins of the male and female flowers of the birch are shown on the same twig. There are various species of birch available, and cross-breeding experiments may very readily be made, owing to the separate-clustering of the staminate and the pistillate flowers.

loid deposited in their bark. And doubtless the same thing is true of most or all other producers of commercial alkaloids.

Seemingly there is a splendid field, then, for the plant experimenter, could he establish a laboratory and experiment garden in the tropics, in the development of improved races of cinchona trees and of numerous other suppliers of medicinal alkaloids. The monetary return from such an enterprise would probably be larger than that which usually rewards the efforts of the plant developer in temperate zones, because the field is virgin, and because there is no present possibility of competition outside the tropics.

It remains to be said that there are a few other trees and shrubs of our own latitude that may advantageously command the attention of the plant developer for the improvement of quantity or quality of the by-products of their life activities that man has found useful.

It seems not unlikely that the horse chestnut, or buckeye, could be so educated as to become a profitable starch producer. At present this tree produces an abundant crop of nuts, but these are worthless because they contain a bitter principle that makes them inedible. Yet the nut of the horse chestnut is very starchy and if the bitter principle could be eliminated there is no reason why it

should not prove both wholesome and nutritious. The West Indians sometimes grind the nuts to make meal. When this is soaked in water the poisonous principle is partially removed, and the residue is cooked and eaten.

I have experimented somewhat in the attempt to test the western buckeye as to its possibilities of improvement. As long ago as 1877, I began work on this tree, and continued the experiments in a small way for a number of years. I observed that there was great variation as to productiveness of trees, as to size of nuts, and also as to bitterness of the nuts themselves.

I am convinced that it would be possible to develop a variety in which the bitter principle would be greatly reduced in amount and perhaps altogether eliminated, and that at the same time a nut having a high starch content could be developed.

It has been found possible with the South American plant called the casaba to utilize roots that contain a poisonous principle for the production of so important a commercial product as tapioca. It is not unlikely that the nuts of the horse chestnut, if developed until it had a still higher starch content, could be utilized in somewhat the same way, even though the bitter principle was not entirely eliminated.

The Buckeye, or Horse Chestnut

Hitherto no commercial use has been made of the large nuts of the buckeye, or horse chestnut, notwithstanding the general distribution of the trees on which they grow. Mr. Burbank suggests that it might be possible by selective breeding to remove their objectionable or poisonous principle, and thus to produce a nut of great commercial value. The buckeye already contains a high starch content.

There are some members of the laurel family, also, that produce commercial products that make them perhaps worthy of attention. The camphor tree is too tender to be grown in our latitudes, but its relative, the sassafras, is a common tree throughout the eastern states, thriving even in New York and New England. Its bark furnishes the characteristic flavoring that is used for perfuming soaps and for similar purposes. The production of the sassafras would not constitute a significant industry under any circumstances, doubtless, yet there would be a measure of scientific interest in testing its capacities for improvement, and not unlikely new uses would be found for its product if it were made available in larger quantity.

Another tribe that furnishes a product of a unique quality is that represented by a familiar wild shrub known in the eastern states as the wax berry or candle berry (*Myrica cerifera*) and sometimes also spoken of as the bay berry owing to the fragrance of its leaves.

This shrub bears an abundance of small berries from which may be extracted a quantity of hard greenish fragrant wax, which was formerly much prized for the making of candles, and which has a certain value for the various other uses to which wax is put.

A Fine Specimen of Laurel

The l a u r e l s *are shrubs of deserved popularity, owing to their hardiness, the beauty of their evergreen foliage, and the exquisite quality of their flowers. Nevertheless, they have been much less introduced into our gardens than they deserve to be. Interesting cross-breeding experiments may be made with the different species.*

A good many years ago while traveling in the east I found a candle berry bush that was of compact growth and that produced a large crop of waxy berries. I collected seed and brought it to California, and for several years worked on the shrub until, by selection, I had developed a variety that produced at least ten times as many berries and ten times as much wax as the average wild plant. At the same time I experimented with a Japanese member of the genus known as *M. nagi* or *M. rubra,* and also with the California species which is a tree growing fifty or sixty feet in height.

I endeavored to cross the three Myricas in the hope of producing new varieties of value, but did not succeed, no doubt because the attempt was not carried out with sufficient pertinacity. The California species produces a wax of much darker color than the eastern one, but of about the same degree of hardiness. I still have several fine blocks of wax that were produced from these shrubs and trees during the time of the experiment. Although not successful in hybridizing the different candle berry shrubs, the experiments were carried far enough to show the possibility of great improvement by mere selection. If there were a market for the wax, the plant might be well worth improving.

Even as it was, I advertised my improved

variety of candle berry, but as no one cared to buy it, it was finally destroyed to make room for other shrubs. This is another case in which a product of intrinsic value has failed to find a market, largely, no doubt, because the plant that produces it has hitherto not been brought under cultivation, and hence has not produced a sufficient crop to bring it to the attention of the public and to create a market.

It would not be surprising, however, if the candle berry should be thought valuable enough in future for development and cultivation on an extensive scale. For the wax that it produces is of unique quality, and it is almost certain to be found of value in connection with some commercial industry.

—Seemingly, there is a splendid field for the plant experimenter, could he establish a laboratory and experiment garden in the tropics for the development of improved producers of medicinal alkaloids.

The Home of a "River Baron"

This house stands on the overflowing banks of the Sacramento River, where land produces crops giving an annual return of one thousand dollars per acre. Note the picturesque and artistic arrangement of the trees and shrubs about the house.

Trees and Shrubs for Shade and Ornament

Some Miscellaneous Tree Experiments

DOUBTLESS the most interesting tree in the world is the Sequoia. The mere fact that this is the most gigantic of all existing trees gives it distinction. But it has added interest because it represents a link with the remote past.

Of course it might be said that any existing vegetable represents a link with the past, since every race has its lines of ancestry tracing back to primordial times. But the Sequoia represents the past in a somewhat different sense, inasmuch as it has maintained more fixedly the traits of its remote ancestors than has been done by any other tree, probably, that now grows in the northern hemisphere, with the possible exception of the tulip tree, which represents a quite different type of vegetation.

The story of the Sequoia's fight for life during the remote geological ages when the climate of the

northern hemisphere was changing, has been outlined in an earlier chapter. Could we know the details of the story, we should doubtless find that the ancestors of the Sequoia migrated southward before the chilling blasts of successive glacial epochs, and made their way northward again in the intervening periods. And of course the present age may represent merely another of these interglacial epochs, during which the Sequoia has carried its return march along the coast to about the fortieth parallel of latitude. It maintains in this location its proud position as the one champion of the ancient traditions. And perhaps it will still maintain them in some remote epoch of the future when another ice age has driven man from the northern hemisphere and reduced the civilization of the twentieth century to a half-forgotten tradition.

Be that as it may, the Sequoia and its daughter, the redwood, stand to-day as sister giants in an age of pigmies. Individual trees that are still young according to the reckoning of their tribe were gigantic centurions according to human estimates when Columbus discovered America.

And Sequoias that are moderately old have witnessed the ceaseless change of the seasons since the period, perhaps, when Moor and Christian were battling for supremacy in Europe in the dark

An Ivy-Clad Tree

Here is a tree fairly encompassed in a draping of English ivy. The effect, to the human eye, is decorative and pleasing as well as anomalous; but the tree must suffer somewhat in proportion as the vine thrives.

age that preceded the segregation of the modern nations of Europe. The patriarchs of the race were living in the days that saw the building of the Egyptian pyramids.

A tree with such racial traditions and with such individual representatives is surely entitled to be considered the most interesting tree in the world.

Whoever has camped in a primeval forest of Sequoias or redwoods will attest that merely to enter into the presence of these colossal antediluvians is to experience an almost overwhelming sense of their grandeur. And it is the common experience that this feeling of awe grows day by day and becomes overpowering if you linger like a lost pigmy in the shadow of the giants.

From our present standpoint the interest in the Sequoias hinges on the possibility of growing seedlings or transplanting saplings for ornamental purposes in the parks and fields. It is rather strange that the attempt to do this has not been carried out more extensively. Curiously enough, the redwoods are grown more in England than they are anywhere in America outside the regions where they are indigenous. But doubtless the climatic conditions account for this. The trees thrive fairly well in the relatively mild climate of England, but they find the winters of the North Central and the Northeastern United States prohibitive.

A "Pepperwood Tree" in Bloom

The photograph suggests the attractive quality of this tree in blossoming time. At other seasons also it is an ornamental tree of value, in regions where it will grow. Unfortunately it lacks hardiness, and is not adapted to the climate of our eastern states.

A tree that has weathered successive ice ages should not mind the winters of the present era, even at the northern boundaries of the United States, one might suppose. But such an inference misses the chief point of the Sequoia's ancestral story. In point of fact, the giant trees are alive today in something like their pristine form because they migrated before the ice sheets and finally found a place of refuge west of the Sierras where they were sheltered from the northern blasts and given protection by the tempered breezes of the Pacific. As compared with the other conifers—pines, spruces, hemlocks, cedars, and the rest—the Sequoias are really tender trees. They are hardy indeed in contrast with their ancestors of still remoter geological times. But they have never developed that extreme hardiness that characterizes their modified and stunted cousins.

Nevertheless it has been found possible to raise the Sequoia gigantia as far north as Central New York. But the tree does not really thrive in regions so inhospitable, and the redwood is even more tender. In central and south-central regions of the United States, however, the giant trees can be grown to better advantage, and here they should find a place as ornamental trees that has not hitherto been accorded them.

In the region of Washington, D. C., the Sequoia

has proved altogether hardy, and of course it may be grown readily anywhere along the Atlantic Coast south of this region. It is a tree of extremely rapid growth, almost equalling the eucalyptus. The redwood also is of such rapid growth under cultivation that it soon overshadows most other trees. Indeed, it grows so rapidly and requires so much room that it is hardly adapted to use as an ornamental tree except in large grounds.

I have raised the giant Sequoia (it is known technically as *Sequoia gigantia*) in the nursery from seed, and the redwood (*Sequoia sempervirens*) from cuttings as well as from seed. The cuttings do fairly well if started in the fall and treated like cuttings of other conifers.

As to the matter of selection and development, the redwood itself may probably be regarded as a comparatively recent variation from the form of the giant Sequoia. The ancestors of the redwood took up their location in the valleys nearer the ocean and were modified until they are considered to rank as distinct species. But the similarity of the two forms is obvious, and the two species stand in a class by themselves—obviously allied to other conifers in the form of leaf and cone and manner of growth, yet so far outranking all others as to be properly thought of as representatives of a unique order of vegetation.

South American Yew Tree

This thrifty and symmetrical seedling, with erect stem and handsome foliage, is a visitor from the tropics, believed to be a yew, growing in Mr. Burbank's grounds for observation and development. It has obvious qualities of attractiveness as an ornamental shrub.

Whether further modifications in the giant trees could be wrought by hybridizing the two forms or by selection among variant seedlings is a question of interest.

Presumably, such modifications could be brought about were there time for it. But in dealing with a tree that is a mere child when it has outlived half a dozen generations of men, the plant developer feels himself in the presence of forces that lie almost beyond his ken.

Moreover the attempt to deal experimentally with the redwood is made difficult by the fact that the tree seldom bears seed. Some of the woodmen claim that it bears once in seven years, but this is doubtless a mere guess, instigated by the popular superstition connected with the number seven. On one occasion, some thirty years ago, I was informed that the redwoods were loaded with seed. I went out with some helpers and gathered a dozen grain sacks or more of the cones, which could be obtained in any desired quantity. On drying the cones I found that the seeds themselves made up half the total weight.

There was a good deal of variation in the cones themselves and in the seed from different trees.

The seed when dried kept its germinating quality for seven or eight years. But only a very small proportion of the seeds will germinate under

any circumstances, even when fresh. This seems to be especially true of seeds collected from the younger trees—a fact that accentuates the already sufficient difficulties that confront the plant developer who cares to undertake the rather discouraging task of experimental breeding with these antique giants.

Nevertheless, it should be recorded that a certain amount of work has been done with the redwood, particularly in the way of selecting trees that bear weeping branches. It has been observed that seedlings usually show the characteristic drooping branches of the parent form. In my experience there is less variation among seedlings of this type than among the normal ones. The latter show a rather wide range of variation of foliage, particularly where seed from different localities is sown. Some are much lighter in color than others, and there are various interesting characteristics that may be noted by a close observer, leaving no doubt that there is sufficient material for the purposes of the plant developer.

Doubtless anyone who has patience to undertake the task will be able to produce various types of redwoods that will reveal interesting characteristics of the remote racial strains that now are so blended in the existing representatives of the family as to be scarcely observable.

Japanese Magnolias

The magnolias have distinction among ornamental shrubs because of their large and beautiful flowers, supplementing their attractive foliage. There is good opportunity for hybridizing experiments, utilizing the species from various parts of the world. Here is a Japanese variety that will be used in such experiments, by combining its strains with those of the familiar American species.

I must not attempt to speak except in a general way of the other members of the great tribe of conifers, the merits of most of which, as ornamental trees, are familiar to every garden and landscape architect.

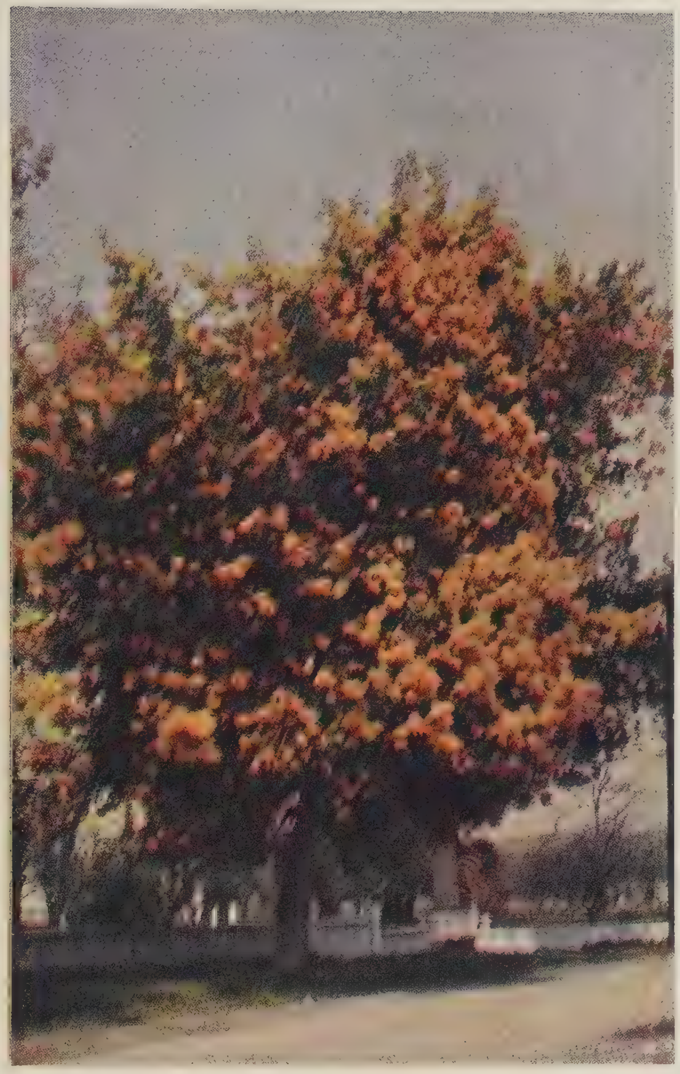
There are some scores of genera and some hundreds of species of conifers but the varieties are too numerous and too intricately blended for accurate computation.

No other single region has so many forms of evergreens, and ones that show such wide range of variation, as the Pacific Coast region. It has been estimated, indeed, that there are as many species of conifers in California as in all the rest of the world.

But the conifers of one kind and another grow everywhere throughout the colder regions of the northern hemisphere, some of them making their way also to parts of the South.

Every one of them is an object lesson in the possibility of plant variation; for as a class they represent a modification of leaf form of the most striking character to meet the exigencies of a changing environment.

Time was, doubtless, when the ancestors of the conifers had flat, spreading leaves like the leaves of other forms of vegetation. But when the climatic conditions changed, the pampering influ-



An Acacia Tree in Bloom

There are several species of acacias, introduced into California from the southern hemisphere, that have become very popular. Their value as ornamental trees is well suggested by this photograph. Unfortunately they are not as hardy as could be desired, although they thrive almost everywhere in California. African species of acacia yield the gum-Arabic of commerce.

ences of warmth and moisture being supplanted by the chill and drought that presaged the onset of perpetual winter, a premium was put on the conservation of plant energies. Whereas before the elements favored the tree that could raise its head highest and thrust out the most luxuriant growth of spreading leaves to absorb the carbon from the heavily laden atmosphere, the time now came when the tree that had a smaller system of branches to nourish and a less expansive leaf system had better chance of maintaining existence.

So in the lapse of ages, the conditions becoming more and more hard, the trees that varied in the direction of smaller size and narrower leaves had an ever-increasing advantage. These survived where their more rank-growing and luxuriant-leaved fellows perished.

Thus generation after generation natural selection operated to modify the size of the trees and to develop a race of trees with narrow leaves, which ultimately were reduced to the form of needles.

Such leaves, offering the largest possible surface in proportion to their bulk, could gain nourishment from an impoverished atmosphere, and at the same time would obstruct the rays of the sun but little, so that the entire foliage of the tree might secure a share of the all-essential light

The California Chinquapin as an Ornamental Tree

This beautiful specimen of the wild California chinquapin grows in Mr. Burbank's grounds at Sebastopol. Its flowers have been used extensively in hybridizing experiments in the course of Mr. Burbank's development of the hybrid chestnuts elsewhere described in this volume. But the chinquapin tree has obvious merits of its own as an ornamental shrub, as this picture clearly testifies.

which now, age on age, became less and less bright as the earth changed the direction of its axis.

Of course there were other trees that did not undergo this modification. But these were forced either to make more rapid migrations to the south or to give up the fight altogether and to submit to extermination. The only ones that were able to maintain existence in the regions where the climate became exceedingly cold were those that had developed the new type of leaf-form, and had learned to conserve their energies to the last degree.

But of course the trees that took on this new habit varied among themselves, and as they spread to different regions such variations were developed and fixed under the influence of different environments, until many tribes of needle-leaved trees were developed so differently as to constitute the races that the modern botanist terms pine and spruce and cypress and juniper and hemlock and yew and cedar.

Representatives of all the chief genera of conifers have recognized a place among ornamental trees and are everywhere popular in cold climates. The variations among the different species are so obvious as to attract the attention of the least observant. And the opportunity to develop any fixed new form is correspondingly good.

The Box Elder

Although popularly known everywhere as an elder, this is really a maple, listed by the botanist as the ash-leaved maple (Acer negundo). It is a hardy tree of rapid growth, much prized for planting in semi-arid regions. There are several varieties, giving opportunity for experiments in selective breeding.

I have raised large numbers of conifers of many species, and have experimented with them in the way of selection, producing in some cases varieties of considerable interest.

I have, for example, developed several beautiful varieties of the spruce, including some very conspicuous forms with weeping foliage; also some that grew very compactly, being strikingly different in appearance from the usual spruce with its long, graceful branches.

Variations in the color of foliage have also been given attention, especially in the case of the Colorado yew cypress (*Abies nordmanniana*). I have observed variations from budding sprouts in the case of this cypress that were of interest. In particular I have seen a branch in a wild species (a bud sport) that would droop several feet below the other branches. Such a branch may generally be propagated by grafting or from cuttings, and a race of trees having this habit may thus be developed. There are corresponding variations in cypress and other conifers grown from the seed.

The Douglas Spruce is a common California form that is quite variable, and in this also the variations sometimes appear as bud sports. The Douglas Spruce has exceptional interest, because it is a tree of very rapid growth. In many cases where a tract of land has been burned over or the

The Irish Yew

The yews are evergreens of a characteristic form of growth that gives them distinction in any group of ornamental trees. They have deserved popularity in England, but have seldom been extensively cultivated in this country. If given an opportunity, they thrive in California, as this picture suggests.

trees have been cut off, there will spring up what at first appears to be a growth of oaks alone. But in fifteen or twenty years the growth of Douglas Spruce will entirely overshadow the oaks, ultimately kiling them off altogether, and presenting yet another illustration of the practical operation of natural selection.

But there is very great variation among the different species of conifers as to rapidity of growth. So there is fine opportunity for the experimenter to select the more rapid-growing trees, and thus to develop a race of timber trees of exceptional value.

The experiment is not difficult because the Douglas Spruce bears seed while quite young, particularly when the trees stand by themselves. The seed remains in the cones for some time, to mature, so that it may be collected at any season of the year. The seeds germinate readily, the seedlings may be easily transplanted, and in general this is one of the easiest conifers with which to work. The hardiness of the tree and its adaptation to all soils and climates are further merits that commend it to the attention of the plant developer, whether he have in mind a tree for ornament or for reforestration.

The experimenter should know, however, that the seed of the spruce, unlike that of the redwood

Cedar of Lebanon

This beautiful specimen of one of the most famous of the world's trees grows beside the cottage known as the "Old Homestead" in Mr. Burbank's garden at Santa Rosa. Its merits as an ornamental tree need no champion, and historical associations give it double attractiveness.

and some other conifers, retains its vitality for a short time only. If attention is given to the securing of fresh seed, the experiments can scarcely fail to go forward successfully.

There are, of course, almost numberless other species and varieties of conifers that hold out inviting opportunities for the plant developer. A beginning may be made with almost any varieties that chance to grow in your dooryard, and the facility with which the different varieties may be reproduced, together with the wide range of variation, offer opportunity for selection and insure interesting developments, provided you have patience to wait for them.

Some Deciduous Favorites

But if there are no broad-leaved trees that quite equal the hardiest of the conifers in capacity to withstand cold and to draw nourishment from rocky soils under disheartening conditions, there are a few tribes of deciduous trees that make at least a commendable effort to rival them.

Notable among these is the birch. But the beech and oak and maple and hickory and walnut also have representatives that are able to withstand the winter in regions where the mercury freezes.

All of these have a certain importance as ornamental trees, but in the main they are valued

A Selected Sumach Tree in Blossom

There are numerous species of sumach, familiar as wild shrubs to everyone who has lived in the country, and even to the casual tourist, owing to the brilliancy of their foliage in the early autumn. For some unexplained reason, the sumach is seldom seen under cultivation, yet it merits a place in the park and dooryard. There is excellent opportunity for experiments in selective breeding, through combining the different species.

rather for their timber, and we have dealt with them when we spoke of forest trees.

There is a considerable company of trees of less hardy character that nevertheless are resistant enough to thrive in the streets, parks and gardens of our northern States if given a certain amount of protection, even though some of them could not make their way in the wilds in competition with the hardy tribes just mentioned.

These trees are less hardy than the others, presumably because they migrated a little more rapidly in the old days of changing climates, and kept far enough away from the ice sheet to be able to retain something of their taste for tropical conditions. They not only retained the broad leaf system, but some of them also retained or developed the habit of bearing handsome flowers—a habit that would have served small purpose for the conifers, since insects could not thrive in cold regions where they remained to battle with the elements.

Doubtless the most interesting of these trees that escaped destruction by flight, and the one that has maintained most fixedly the traditions of the Mesozoic era is the tulip tree (*Liriodendron*).

This beautiful tree, with its unique broad glossy leaves and handsome flowers is now the lone representative of its genus. One species alone

The Judas Tree or Red-Bud

This is a hardy tree of very wide distribution, the eastern species thriving from New York to Florida. There are three other species, one indigenous to Europe, the second to Japan, and the third growing along the Pacific coast. Interesting breeding experiments might be made by combining the various species. The tree is peculiarly attractive at the flowering time, early in the spring, before the leaves appear.

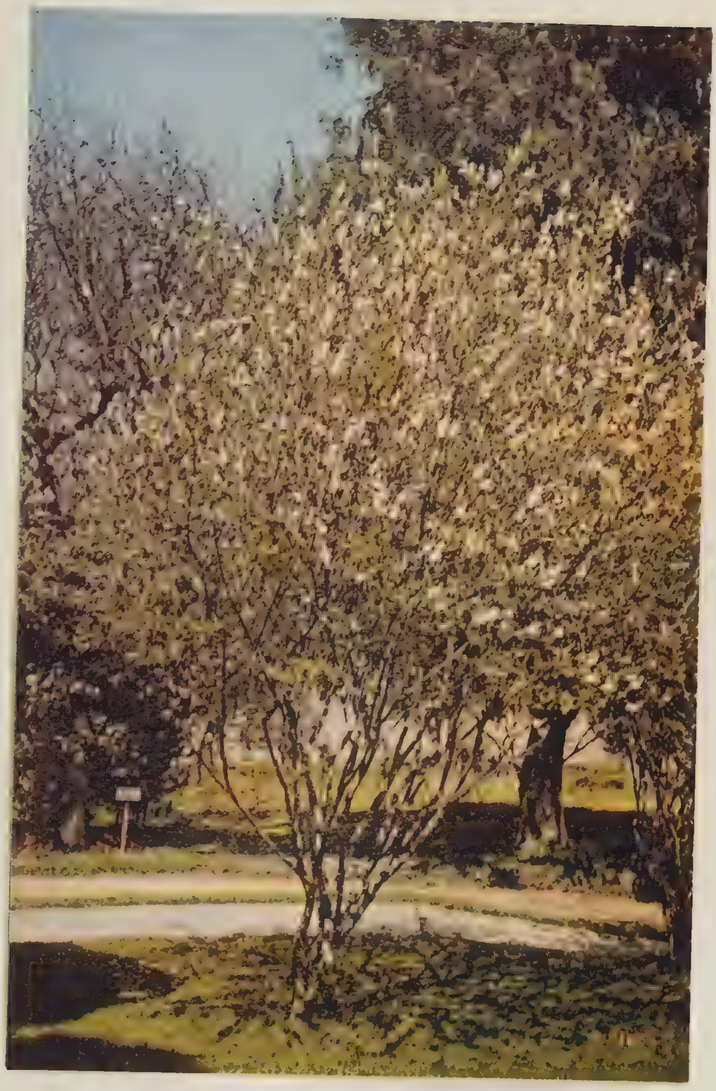
survives as the remnant of a tribe that flourished abundantly in the Mesozoic age. This species made its way to what is now the southern part of the United States, and has kept up its aristocratic traditions throughout intervening ages of such vast extent that it staggers the mind to attempt to grasp their significance.

The thoughtful person cannot well escape a feeling of awe as he stands in the presence of this representative of a race that in the main was gathered to its fathers at a time when the ancestors of man were perhaps still progressing on all fours.

But, traditions aside, the tulip tree of to-day is a thing of beauty, prized for itself, regardless of its ancestry. It makes a fine tree for avenue, dooryard, or park, and it may be grown as far north as New York and New England.

Being a monotypic tree, one would not expect it to show very great variation. But no very keen powers of observation are required to see that the tulip trees are not identical, and doubtless their variation is enough to afford opportunities for interesting experiments, though there is nothing on the earth at the present time with which to combine them.

Exceptional interest should attach to a line of experiment in which the plant developer is dealing with racial traditions of such antiquity and such



An Ornamental from the Tropics

This is one of many unidentified shrubs which have been received by Mr. Burbank from foreign lands. Unfortunately it is often impossible for him to obtain the data necessary to identify plants so received. But all seeds, bulbs or roots sent him are invariably planted with the hope that some useful quality may develop.

fixity. Meantime, the fact that the tree has a beautiful flower gives opportunity for a line of experiment that is usually possible only among herbs and bushes, inasmuch as most of our trees, as the reader is well aware, are wind-fertilized, and hence do not bear conspicuous blossoms.

There are several other trees, however, that resemble the tulip tree in the matter of blossom bearing, and that are not altogether unlike it in general appearance, some of which have corresponding interest, being representatives of ancient forms, even if not quite rivaling the tulip tree in the length of their unmodified pedigrees.

The catalpa and the magnolia may be named as perhaps the chief representatives of these flowering trees. Both of these are represented by several species, and the representatives of each are subject to considerable variation.

There are at least two distinct hybrid catalpas, involving three species, and I have noted great difference in the rapidity of growth of seedlings; also variation in color and abundance of flowers, in length of seed-pods, and in manner of growth of the trees themselves, some being much more upright that others.

I have seen magnolia hybrids also, and have thought it matter for surprise that there are not more of them, for the trees are readily cross-

Live Oak Pasture Near Santa Rosa

The California oaks have peculiar picturesqueness; and among them the live oak has especial distinction. The specimens here shown reveal the influence of prevailing winds, in that their trunks depart from the perpendicular, but they have the characteristic sturdiness of their tribe, and they constitute a feature of the landscape that is appreciated by every lover of nature.

fertilized. Doubtless the fact that different species bloom at different seasons largely accounts for the relative infrequency of natural crossing.

There is an opportunity to work with the catalpa, and I could scarcely mention a plant that seems to me to give better promise for experiments in crossing and selection than the great family of magnolias.

If the seeds are planted while fresh, they germinate readily. The seedlings are easily raised—almost as easily as apples or pears.

Among the magnolia seedlings now growing on my grounds, there are some that will grow three or four feet the first season, while others grow as many inches. Some have a branching habit, and others form an upright front. The leaf varies in breadth and length and in general appearance. Some are early bloomers and some are late bloomers. There are different shades of flowers. All in all, there is abundant opportunity for interesting experiments in selective breeding.

Among other interesting deciduous trees, all of which afford ready opportunity for experimentation, are the acacia and its relative the locust (the seeds of which may best be made ready for germination by boiling), the alder, which is extremely variable and with which I have made interesting experiments; the ash, which affords excellent

chances for hybridization, and is especially promising for timber; and the hawthorne, which has attractive flowers and fruit that are subject to a wide range of variation, and which has exceptional interest because of its not very remote relationship with the great tribe of trees that furnish our chief orchard fruits.

The names of the dogwood, the pepper tree, the tree cranberry and numerous others might be added, but regarding each of them substantially the same thing might be said. All offer excellent opportunities for selective breeding; but few or none of them have been extensively worked with hitherto.

The Finest of Ornamental Trees

There is one peerless tree, however, that I must single out for a few added words of special mention in concluding this brief summary of the more notable among the ornamental trees.

This is the elm, a tree that occupies a place apart, having scarcely a rival when we consider the *ensemble* of qualities that go to make up an ideal ornamental and shade tree.

Whoever has visited an old New England village, and has walked through the corridors of elms or looked down the vista of streets arched over by the interlocking branches of the rows of trees on either side, will not be likely to challenge

Mr. Burbank's Hybrid Elm

This interesting tree was grown from a cutting brought from Massachusetts by Mr. Burbank, and grafted on the roots of a California elm. The parent tree was a hybrid elm of extraordinary size. The tree here shown, which stands beside Mr. Burbank's "Old Homestead" at Santa Rosa, has grown with astonishing rapidity. Its unique history gives it altogether exceptional interest.

the preëminence of this tree. Nothing could more admirably meet the purposes of a shade and avenue tree.

The English elm, which is a more compact grower than the American species, has been widely planted in California. But the American elm thrives here also, although not native to the coast, and it is much less subject to insect pests than is the European species; also the English elm is stiff, and quite lacking in the graceful lines that the American elms so naturally assume.

There is a considerable range of variation among American elms, notably in the size of the leaves, and the openness or compactness of growth.

Indeed the variation is so great that it is never wise to plant a row of seedling elms along a street or roadside. It is much better in the interest of uniformity to secure good roots and then graft them with cions of a single variety.

The slippery elm, which grows in the same regions with the common American species, is a tree of more compact growth, but on the whole not to be compared with the other species. There are natural hybrids, however, between the American elm and the slippery elm that exceed either parent in size, and sometimes are of surpassing beauty.

The largest tree that I have ever seen in New England was an elm that grew in Lancaster, my boyhood home, and which I have reason to believe was a hybrid.

As I was born and brought up under the elm I have naturally an affection for them greater perhaps that for any other tree. On a visit to my old home I secured branches of the gigantic hybrid and brought them to California, and grafted them on roots of a seedling of the American elm on my place at Santa Rosa.

When this grafted tree was only fifteen years old, it was two and a half feet in diameter. Its hybrid character was obvious to all botanists who examined it.

Doubtless this accounts for its extraordinary rapidity of growth. This was of course a natural hybrid, but it stands to-day as an object lesson in the possibility of hybridizing various species of elms and thus producing a tree of extraordinary rapid growth.

I have not experimented further with the elm in this direction; but the hybrid tree that thus reproduced the personality of a giant elm in the shadows of which I passed my boyhood—a souvenir that links the home of my mature years with the home of my ancestors—is a source of perpetual pleasure.

[End of Volume XI]

List of Direct Color Photograph Prints in Volume XI

Acacia

Almond

Baler

Birch

Butternut Tree

Cedar

Chestnut

Cypress

Elder

Elm

Evergreen

Eucalyptus

Fir Tree

Hazelnut

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

Yew Tree